OTOPLASM

DR BEALE.

this now popular notion: it may be that the tendency of modern research is, as has been said, indubitably and strongly in this direction,—but some of us cannot feel satisfied that this is really so. Surely it is not too much to ask that the exact way should be pointed out in which new facts afford support to the doctrine, and that we should be furnished with something more definite to guide our reason than what is called the "*tendency*" of investigation, of thought, or opinion; for this "tendency," when carefully analyzed, will sometimes be found to amount only to this, that certain influential persons have determined that a particular opinion shall be widely taught, or a particular theory agreed upon shall be expounded and diffused as widely and as quickly as possible.

Disclaiming authority of every kind, the adherents of the new school of opinion profess to influence others, and to be influenced themselves, by reason alone. But by urging "the tendency of investigation" and "the spirit of modern thought" in favour of doctrines they cannot support by evidence, they appeal to the shadow of an authority which they affect to despise. Every student has undoubted right to require that scientific doctrines, which he is asked and expected to accept as true, should be supported by facts rather than by the authority of tendencies and prophecies. In favour of regarding living beings as mere machines built by force alone, maintained and preserved by force, and even created by force, it is true, very positive statements have been made; but these have been, for the most part, supported by arguments more ingenious than conclusive. I for one am ready to accept these views, no matter what change

in opinions, beliefs, or hopes that acceptance may involve, provided only they are shown to rest upon facts of observation and experiment. But should mere authority alone induce any conscientious, thoughtful man, who has devoted himself to the study of nature, to believe and confess that a living, moving, growing thing is but a force-created, force-impelled machine? When we watch the lowest forms of living matter under high magnifying powers, do we learn anything to justify us in accepting such a view? When we ask our confident teachers of the new philosophy to assist us, we get dogmatic assertions, but nothing by way of explanation. Grand words are freely used, but the terms employed are not defined. It is, however, true enough, that men eminent among philosophers, as well as some of the most distinguished living physicists, chemists, and naturalists, have accepted this physical theory of life. They have taught that life is but a mode of ordinary force, and that the living thing differs from the non-living thing, not in quality, or essence, or kind, but merely in degree. They do not attempt to explain the difference between a living thing and the same thing dead. They would perhaps tell us that living and dead are only relative terms; that there is no *absolute* difference between the dead and living states; and that the thing which we call *dead*, is, after all, only a few degrees less actively living than the thing we say is *alive*. But is this sort of reasoning convincing, seeing that although matter in the living state may suddenly pass into the dead state, this same matter can never pass back again into the living condition? Those who advocate this doctrine do not believe in the annihilation of force, when

a living thing suddenly passes from the living into the dead state; but yet they do not demonstrate the new form or mode which the departing life-energy assumes, or explain to us what in their opinion becomes of it. If the dead thing only differs from the living thing by a few degrees of heat or units of force, why can we not, by supplying more heat or force, prevent dissolution, or cause the actions to go on again after they have once stopped?

In fact this view has been supported by assertions instead of by facts, and of the arguments hitherto advanced in its favour by its most powerful advocates, all are inconclusive, and some quite unjustifiable. He who chooses may accept upon faith as an article of belief the dogma that all the actions of living beings are due to ordinary forces only; but it is absurd to put forward such a conclusion as if it had been proved, or as if it were in the existing state of knowledge capable of proof. So long as the advocates of the physical doctrine of life contented themselves with ridiculing "vitality" as a fiction and a myth, because it could not be made evident to the senses, measured or weighed, or proved scientifically to exist, their position was not easily assailed; but now when they assert dogmatically that vital force is only a form or mode of ordinary motion, they are bound to show that the assertion rests upon evidence, or it will be regarded by thoughtful men as one of a large number of fanciful hypotheses, advocated only by those who desire to swell the ranks of the teachers and expounders of dogmatic science, which, although pretentious and authoritative, must ever be intolerant and unprogressive.

PROFESSOR OWEN'S NEW VIEWS.

PROFESSOR OWEN has lately avowed his belief in the doctrine that the so-called vital forces are really ordinary physical forces. Unlike many advocates, however, he admits that "on one or two points" proof is wanting. But Owen goes much farther than the most advanced microscopical observers and scientific investigators. He maintains that the formation of living beings out of *inanimate matter*, by the conversion of physical and chemical into vital modes of force, is going on *daily and hourly!* The evidence he has adduced in favour of this strange view, it need scarcely be said, is scanty, uncertain, and unconvincing; while a mass of facts and arguments which have been adduced in favour of the opposite conclusion, *that every particle of living matter comes from a pre-existing particle*, has been unconsciously neglected or purposely ignored.

It is very significant that so great a master is unable to suggest a better instance of the analogy which he affirms exists between physical and vital actions than is afforded by magnetism. He says that there is nothing peculiar to living things in their power of *selecting* certain constituents, because a magnet *selects* also. Let the reader consider how different is the process called *selection* in these two cases. A magnet, says Owen, *attracts* towards it only certain kinds (a certain kind?) of matter. Is there, then, no difference between *selection* and *attraction*? Nor, he further observes, is death characteristic of things living

only; for if the steel be unmagnetized, is it not "dead?" Devitalize the sarcode (living amœba), unmagnetize the steel, and both cease to manifest their respective vital or magnetic phenomena. In that respect both are "defunct." "Only," remarks the same authority, "the steel resists *much longer* the surrounding decomposing agencies;" and I would add, but this Owen would regard as a matter of the utmost indifference, you can unmagnetize and remagnetize the magnet as often as you like, but you can only kill the amœba once, and you can never revitalize it.

In answer to my objections to some of his statements, Professor Owen observes that "there are organisms (Vibrio Rotifer, Macrobiotus, &c.) which we can devitalize and revitalize—devive and revive—many times."* That such organisms can be *revived*, all will admit, but probably Professor Owen will be alone in not recognizing any distinction between the words *revitalizing* and *reviving*. The animalcule that can be *revived* has never been dead, but that which is not dead cannot be *revitalized*. The difference between the living state and the dead state is absolute, for that which has once lost its life can never regain it. The half-drowned man that can be revived has never been dead.

If Owen regards the (apparently) dried animalcule as being "as completely lifeless as is the drowned man whose breath and heat have gone, and whose blood has ceased to circulate," he will not find many to agree with him; for will not a drop of water resuscitate or revive the one, but who shall revitalize the other?

* "The Monthly Microscopical Journal," No. V, May 1, 1869, p. 294.

Note on Ciliary Action.

In the case of ciliary action we have an example of a movement which, though not strictly a vital movement, like that of the amœba (*see* p. 39), is really dependent upon changes which are a direct result of vital phenomena. The cilium itself is not composed of living matter, but its base is certainly in very intimate relation with matter that is alive. The latter may indeed be actually prolonged into the base of the cilium. The vibratile movement is probably due to an alteration taking place in the tension of the fluid which pervades the tissue, induced by the action of the living matter of the cell. The rate of vibration varying according to the rapidity with which the living matter of the cell absorbs nutrient substances, and undergoes conversion into formed matter, or in other words, the rapidity with which the formation of new living matter and the death of the old particles takes place. When ciliary action ceases, we cannot, I think, say that each individual cilium dies, for after all action has ceased a little alkaline fluid will cause the cilium to vibrate again actively. We must not, therefore, infer that the dying cilium has been revived or the dead cilium revitalized by the liquor potassæ, for the fact seems rather to point to the conclusion that the action of the cilium which occurs during life is due to physical changes, and is not a vital action.

My friend, Dr. Rutherford, has suggested that the fact of the cessation of movement at the base of the cilium, while the thin part still continues to vibrate, might be advanced as an argument against the views advocated by me in the following pages, and if the *cilium* itself were composed of living matter, like the body of an amœba, such an objection would undoubtedly hold: but if, on the other hand, the movement is physical, due to alterations in the currents of fluid through the cell, we should expect that it would continue longer at the apex than at the base, for the simple reason that an impulse which would be sufficient to make the thin free part vibrate freely would be insufficient to move the thicker portion attached to the cell. We cannot say that the cilium dies from base to apex, for the whole vibratile appendage is as destitute of life while it is yet vibrating actively, as after it has ceased to move, and if we could only make fluid flow through the cell after its death interruptedly in the same

direction, and with the same force as it is made to flow during life by the action of the living matter, ciliary movement would continue, although the living matter of the cell was actually dead. It is most important to distinguish between *vital movements* occurring in living matter, and *mechanical movements* which result from alterations in tension, the flow of currents, &c., *consequent upon changes effected by living matter.*

MR. GROVE ON EXPERIMENTAL ORGANISM.

MR. GROVE has recently* affirmed that "in a voltaic battery and its effects" we have "the nearest approach man has made to experimental organism:" but surely it should be shown in what particulars a voltaic battery resembles an organism. All organisms come from pre-existing organisms, and all their tissues and organs are formed from or by a little clear, transparent, structureless, moving matter which came from matter like itself, but may increase by appropriating to itself matter having none of its properties or powers. Now, voltaic batteries do not grow or multiply, nor do they evolve themselves out of structureless material, nor, if you give them ever so much pabulum in the shape of the constituents of which they are made, do they appropriate this. Where too is the chemist who gives what is to be selected? What then does Mr. Grove mean by asserting that a voltaic battery is the nearest approach man has made to experimental organism? Has man yet made the slightest approach to experimental organism? If any apparatus we could contrive developed all possible modes of force—motion, heat, light, electricity, magnetism, chemical action, and any number of others yet to be discovered—that apparatus would still present no approach whatever to any organism known. Of course such a thing might he *called* an organism, just as a watch, or water, or a gas, or an elementary substance may be called a creature, or a worm

* "British Medical Journal," May 29, 1869, p. 486.

a machine; but everything that lives—every so-called living machine—grows of itself, builds itself up, and multiplies, while every non-living machine *is made, does not grow, and does not produce machines like itself.* Mr. Grove further says that in the human body we have chemical action, electricity, magnetism, heat, light, motion, and possibly other forces "contributing in the most complex manner to sustain that result of combined action which we call life." Here it seems to be affirmed that forces sustain the result of their own combined action, but surely this is only asserting that these forces sustain themselves. Heat, light, electricity, etc., sustain the result of the combined action of heat, light, electricity. It is moreover said that what we call *life* is the result of the combined action of motion, heat, light, electricity, etc., which are but different forms or modes of one force. But as everybody knows we may have any and all modes of force without life. Life, therefore, involves something besides force, or is something different from it.

Those who teach that *life* is the sum of all the actions going on in a living body, forget that these actions are not all of the same kind. Of some we know very much, but of the nature of others we know nothing. In every living thing there are *physico-chemical actions*, which also occur out of the body, and *vital actions.* These last are peculiar to living beings, and cannot be imitated. In galvanic batteries, and in other arrangements made by man, we may have physico-chemical actions, but never anything at all like *vital* actions. Of course, authority may decree that henceforth the terms "*living galvanic battery*," "*vital machine*," "*animated steam engine*," shall be employed, and that a man shall be called a "*physico-chemical apparatus*," or a "*kynetic*," or "*electric machine*," but the nature of the things themselves could not be changed in the least degree by authority, however much the names by which they were known were altered.

PROTOPLASM.

The term "Protoplasm" is now applied to several different kinds of matter,—to substances differing from one another in the most essential particulars. It seems, therefore, very desirable that its meaning should be accurately defined by those who employ it, or that it should be superseded by other words. If certain authorities were asked to define exactly the characters of the matter which they called protoplasm, we should have from those authors definitions applying to things essentially different from one another. Hard and soft, solid and liquid, coloured and colourless, opaque and transparent, granular and destitute of granules, structureless and having structure, moving and incapable of movement, active and passive, contractile and non-contractile, growing and incapable of growth, changing and incapable of change, animate and inanimate, alive and dead,—are some of the opposite qualities possessed by different kinds of matter which have nevertheless been called protoplasm.

A definition of protoplasm, most probably written by the late Professor Henfrey in "Griffith and Henfrey's Micrographic Dictionary," is as follows:—"*Protoplasm.*—The name applied by Mohl to the colourless or yellowish, smooth or granular viscid substance, of nitrogenous constitution, which constitutes the formative substance in the contents of vegetable cells, in the condition of gelatinous strata, reticulated threads and nuclear aggregations, &c. It is the same substance as that formerly termed by the

Germans 'schleim,' which was usually translated in English works by 'mucus' or 'mucilage.'" The surface of this mass constituted the "formative protoplasmic layer" which was supposed to take part in the formation of the cellulose wall of the vegetable cell. This was regarded by Von Mohl as a structure of special importance distinct from the cell contents, and it was named by him, in 1844, the "primordial utricle."

In cases where protoplasm appears as a simple transparent homogeneous substance, several layers have been described, and it has been supposed that these different layers are concerned in different operations. This view has been extended to many forms of protoplasm, and the movements which occur have been attributed to the presence of two or more layers differing in density.

Clear, homogeneous protoplasm, it has been said, undergoes vacuolation, and becomes honeycombed, the spaces being filled with watery matter. In some instances, this change proceeds until mere protoplasmic threads are seen stretched across the cavity. The transparent fluid material occupying the spaces and the intervals between the threads supposed to be the less important matter, and yet it is the living, growing, and moving substance; while the threads and walls of the spaces are composed of matter which has ceased to manifest these properties—matter which no longer lives, and which has been *formed from the living matter*. But we may fairly ask if this lifeless, passive, formed matter, which cannot move or grow or multiply of itself, which is but a product of the death of protoplasm, is nevertheless to be called by the same name as the living,

moving substance which it once was? If this be so, there ought to be no recognizable difference between matter which is actually alive and the substances which result from its death.

So far, then, we have seen that the term protoplasm has been applied to the matter within the primordial utricle of the vegetable cell, to that clear substance which undergoes vacuolation and fibrillation, and to the matter forming the walls of the vacuoles and the threads or fibrillæ. Still more recently, Von Mohl's primordial utricle has been called protoplasm by Professor Huxley, who some years before restricted the term to the matter within the primordial utricle, which matter at that time he regarded as an "accidental anatomical modification" of the endoplast, and of little importance.* The nucleus, and with it the protoplasm, Mr. Huxley thought, exerted no peculiar office, and possessed no metabolic power. Now, however, he considers "protoplasm" of the first importance; and under this term includes, I imagine, not only the primordial utricle and the "accidental anatomical modifications" it encloses, but the fully-formed cellulose wall of the vegetable cell. His "*endoplast*" and "*periplastic substance*" of 1853 together constitute his "protoplasm" of 1869. The old views are modified, and although the results of researches made during the last few years are scarcely alluded to, the writer evidently has felt that certain changes must be made. So the vacuoles of his periplastic substance become silently tenanted by simple or nucleated protoplasms endowed with "subtle influences" which our author may yet admit to have existed before his

* "The Cell Theory," "Med. Chir. Rev.," October, 1853.

periplastic substance was formed. Next he may discover that the endoplast is of the highest importance instead of no importance at all, and then there is an easy step to the doctrine that the *periplastic substance is formed by and from the protoplasm which has properties and "subtle influences" of a remarkable kind, but is not endowed with the absurd fiction of vitality.*

Max Schultze included under the head of protoplasm the active moving matter forming the sarcode of the Rhizopods as well as the substance circulating in the cells of vallisneria, the hairs of the nettle, and other vegetable cells; and now it is generally admitted that the active, moving matter constituting the white blood-corpuscle, the mucus and pus corpuscle, and other contractile bodies widely distributed, is essentially of the same nature. The movements characteristic of this matter have been attributed to an inherent property of contractility; and this property has been held by some to be characteristic of, and peculiar to, protoplasm. Kühne considers all contractile material to be protoplasm, and includes the different forms of muscular tissue in the same category as the matter of the amœba, white blood-corpuscle, &c. But if we apply the term protoplasm to the contracting muscular tissue which exhibits *structure*, as well as to the living moving matter of the amœba, &c., in which no structure at all can be made out, it is obvious that these must be regarded as *essentially different kinds of protoplasm*, because they differ in properties which are essential and of the first importance. The contractile movement of the amœba, white blood-corpuscle, &c., is a phenomenon very different from the con-

traction of muscular tissue. In the first, movements occur in every direction, while the last is characterized by a repetition of movement in two definite directions only. And when we come to study the matter which is the seat of these two kinds of movements respectively, we find very important differences. The matter of the amœba, white blood-corpuscle, &c., grows. *It takes up matter unlike itself, and communicates to it its own properties.* Now, muscular tissue does not do this. In short, the first kind of matter acts and moves *of itself;* but the last can only *be acted upon and made to move.* The first may be compared with a spring, as yet undiscovered, which not only winds itself up and uncoils, but every part of which moves in any direction, and can make new springs out of matter which has none of the properties of a spring; the last with a spring which can only uncoil itself after it has been wound up.

Further, the term protoplasm has not been applied only to the matter of which the amœba, the sarcode of the foraminifera, &c., is composed, and that which constitutes the white blood-corpuscle and such bodies, but the matter which is gradually assuming the form of tissue has been considered to be of the same nature. The radiating fibres of the caudate nerve-cells of the spinal cord have been termed protoplasm fibres, and the outer part of the nerve-cell with which they are continuous is composed of the same substance. The axis cylinder of the dark-bordered nerve-fibres and the fine ultimate nerve-fibres in peripheral parts have been looked upon as a form of protoplasm; but it is hardly necessary to remark that, whatever may be the nature of the material of which nerve-fibres and the outer part of nerve-cells are composed, it possesses properties

very different from those manifested by the amœba, white blood-corpuscle, etc., and is destitute of the powers which characterize the matter constituting these bodies. Here again we find the term protoplasm applied to different kinds of matter or to matter in very different states.

But unfortunately we have by no means exhausted the confusion which has resulted with regard to protoplasm, for the name has been applied also to the outer, hard, dead part of epithelial cells and by implication to all corresponding structures.

Protoplasm the Physical Basis of Life.—In order to convince people that the actions of living beings are not due to any mysterious vitality or vital force or power, but are in fact physical and chemical in their nature, Prof. Huxley gives to matter which is alive, to matter which is dead, and to matter which is completely changed by roasting or boiling, the very same name. The matter of sheep and mutton and man and lobster and egg is the same, and, according to Huxley, one may be *transubstantiated* into the other. But how? By "subtle influences," and "under sundry circumstances," answers this authority. And all these things *alive*, or *dead*, or *roasted*, he tells us are made of protoplasm, and this protoplasm is the *physical basis* of life, or the basis of *physical life*.* But can the discoverer of "*subtle influences*" afford to sneer at the fiction of vitality? By calling things which differ from one another in many qualities by the same name, Huxley seems to think he can annihilate distinctions, enforce identity, and sweep away the difficulties which have impeded the progress of previous philosophers in

* The iron basis of the candle, and the basis of the iron candle are expressions evidently interchangeable.

their search after unity. Plants and worms and men are all protoplasm, and protoplasm is albuminous matter, and albuminous matter consists of four elements, and these four elements possess certain properties, by which properties all differences between plants and worms and men are to be accounted for. Although Huxley would probably admit that a worm was not a man, he would tell us that by "subtle influences" the one thing might be easily converted into the other, and not by such nonsensical fictions as "vitality," which can neither be weighed, measured, nor conceived.*

* But this is not the first time Mr. Huxley has indulged in adroit word-tricks and inapposite illustrations. After referring to the anatomy of the horse, he says, in his "Lectures to Working Men," page 11: "Hitherto we have, as it were, been looking at a *steam-engine with the fires out, and nothing in the boiler*; (!) but the body of the living animal is a beautifully-formed *machine*." And it would be easy to point out in many of his writings, vague remarks of the same sort with similes, calculated rather to mislead than to assist the judgment of students. Take, for example, his far-fetched observations in the first number of the "Academy," page 13, about the kitchen clock, which cries "cuckoo," and shows the phases of the moon, and the death-watch machine, "a learned and intelligent student of its works," ticking like the clock in the clock case. We are told to "substitute 'cosmic vapour' for 'clock,' and 'molecules' for 'works,' and the application of the argument is obvious." (!) The argument relates to the "forces possessed by the molecules of which the primitive nebulosity of the universe was composed," by the mutual interaction of which forces the whole world living and not living has resulted. "If this be true" (doubtfully suggests the Professor) "it is no less certain that the existing world lay, potentially, in the cosmic vapour; and that a sufficient intelligence could, from a knowledge of the properties of the molecules of that vapour, have predicted, say the state of the Fauna of Britain in 1869, with *as much certainty* as one can say what will happen to the vapour of the breath in a cold winter's day." (!) These remarks are printed under the heading "SCIENCE AND PHILOSOPHY."

Some among those who work at and think over these matters doubt if many of Prof. Huxley's assertions are at all justified by his facts, and many are unable to accept arguments which by him seem to have been considered quite conclusive. I shall therefore venture to draw attention to some of the views he has recently expressed in his paper, "On the Physical Basis of Life," published in the "Fortnightly Review", February 1st, 1869.

Up to this time all observers have agreed in opinion that the cell or elementary part of the fully-formed organism consists of different kinds of matter, and it has been supposed that distinct offices were performed by some of these. They have been variously named. Cell-wall, cell-contents, nucleus, nucleolus, periplast, endoplast, primordial utricle, protoplasm, living matter and formed matter, are not all the terms that have been proposed. I think Professor Huxley is the first observer who has spoken of the cell in its entirety as a mass of protoplasm, and the only one who has ever asserted that any tissue in nature is composed throughout of matter which can properly be regarded as one in kind. This view is quite incompatible with many facts, some of which have been alluded to by Mr. Huxley himself.* I doubt if in the whole range of modern science it would be possible to find an assertion more at variance with facts familiar to physiologists than the statement that "beast and fowl, reptile and fish, mollusk, worm, and

* "The original endoplast of the embryo cell," Huxley says, in 1853, "has grown and divided into all the endoplasts of the adult," and "the original periplast has grown at a corresponding rate, and has formed one *continuous and connected envelope* from the very first."

polype," are composed of "masses of protoplasm with a nucleus," unless it be that still more extravagant assertion that what is ordinarily termed a cell or elementary part is a *mass of protoplasm*;—for can anything be more unlike the semi-fluid, active, moving matter of amœba protoplasm, than the hard, dry, passive, external part of a cuticular cell or of an elementary part of bone?

I cannot forbear quoting in this place the following passage, which certainly requires explanation. After stating that the substance of a colourless blood-corpuscle is an active mass of protoplasm, Mr. Huxley remarks that "*under sundry circumstances* the corpuscle dies (!) and becomes distended into a round mass, in the midst of which is seen a smaller spherical body, which existed, but was more or less hidden in the living corpuscle, and is called its *nucleus*. Corpuscles of *essentially similar structure* are to be found in the *skin*, in the *lining of the mouth*, and scattered through the *whole framework of the body*." Now, what can be meant by a white blood-corpuscle dying and becoming distended into a round mass under sundry circumstances? Mr. Huxley goes on to say that at an early period of development the organism is "nothing but an aggregation of such corpuscles," that is, of corpuscles (elementary parts or cells) like those "found in the skin, in the lining of the mouth, and scattered through the whole framework of the body." This assertion is incorrect, inasmuch as the corpuscles in the embryo consist almost entirely of (living) matter like the white blood-corpuscle, while those of which the skin (cuticle) and most of the tissues of the adult are composed consist principally of formed matter with a very

little of the other (living) matter, and the oldest particles of cuticle are entirely composed of hard formed matter. Here, as in other cases referred to by Huxley, no distinction is drawn between that which is *living, growing*, and *forming;* and that which has *been formed* and is *destitute of all powers of life and growth.* No distinction between living matter and lifeless matter! Both are confused together under the term "protoplasm," for which might be substituted "organic matter" or "albuminous matter." Huxley terms the particles of epithelium of the cuticle and of mucous membranes, masses of protoplasm. He says beasts and fowls, reptiles and fishes, are all composed of structural units of the same character. Now, this mass of protoplasm, this unit, consists partly of *lifeless* and partly of *living* matter. The outer part, which may be dry and hard, and is lifeless, may be undergoing disintegration, and is perhaps being taken up by other living organisms, but is nevertheless, according to this view, just as much protoplasm as the living, growing, moving matter itself. It does not signify how many different things may be comprised in the cell or elementary part, in what essentially different states these things may be, how different parts may differ in properties—they constitute protoplasm. A muscle is protoplasm; nerve is protoplasm; bone, hair, and shell are protoplasm; a limb is protoplasm; the whole body is protoplasm, and of course bone, hair, shell, etc., are as much "the physical basis of life" as albuminous matter and roast mutton. But surely it would be less incorrect to speak of such "protoplasms" as the physical basis of *death* or the physical basis of *roast*, than to call dead and roasted matter the physical basis of

life. No anatomical investigation is necessary to enable us to detect this substance. Every beast, fowl, reptile, worm, or polyp that we see is protoplasm. Everything that lives or has lived is protoplasm, variously modified.*

Mr. Huxley seems to maintain that protoplasm may be killed and dried, roasted and boiled, or otherwise altered, and yet remain protoplasm; but his "protoplasm" is after all only albuminoid or protein matter.† Huxley says lobster-protoplasm may be converted into human protoplasm, and the latter again turned into living lobster. But the statement is incorrect; because, in the process of assimilation "protoplasm" is entirely disintegrated, and is not converted into the new tissue in the form of protoplasm at all; and he must permit me to remark that sheep cannot be transubstantiated into man, even by "subtle influences," nor can dead protoplasm be converted into living protoplasm, or a dead sheep into a living man. And what is gained by calling the matter of dead roast mutton and of a living growing sheep by the same name? If the last is the physical basis of *life* one does not see how the first can be so too, unless roast mutton and living sheep are identical; but surely Mr. Huxley does not really mean to assert this.

It is remarkable that Huxley himself, some sixteen years

* The term "variously modified" perhaps includes the terms *living* and *dead*, and, according to Mr. Huxley, expresses with sufficient exactness the difference between the *living* and *dead* states.

† Mr. Huxley says, "all protoplasm is proteinaceous; or, as the white or albumen of an egg is one of the commonest examples of a nearly pure protein matter, we may say that all *living matter* is more or less albuminoid." If the white of an egg is living matter, why not its shell?

ago, drew a distinction between living and non-living matter, which he now, without any explanation, utterly ignores. He remarked that the stone, the gas, the crystal, had an *inertia*, and tended to remain as they were unless some external influence affected them; but that living things were characterized by the very opposite tendencies. He referred also to "the faculty of pursuing their own course" and the "inherent law of change in living beings." In 1853, the same authority actually found fault with those who attempted to reduce life to "mere attractions and repulsions," and considered physiology "simply as a complex branch of mere physics." He also remarked that "vitality is a property inherent in *certain kinds* of matter."

Bathybius.—I will now draw attention to a fanciful form of marine protoplasm, supposed to be very widely extended at great depths, which has been much discussed of late, and concerning the nature of which much difference of opinion is entertained. From the protoplasm of the amœba and certain forms of foraminifera, we pass, it is said, to larger and more extended sheets of this substance, included under the head of "urschleim," and constituting the organisms of the simplest animated beings, which have been included by Hæckel in the genus *Moner*. It would be wrong to omit all mention of this subject, as it is very interesting and of great importance, although I have not given much attention to it. I shall therefore quote the observations of others so far as they appear to me to bear upon the consideration of the nature of protoplasm.

In the "Microscopical Journal" for October, 1868, is a

memoir by Professor Huxley, "On some Organisms living at great Depths in the North Atlantic Ocean," in which he states that the stickiness of the deep-sea mud is due to "innumerable lumps of a transparent gelatinous substance," each lump consisting of *granules*, *coccoliths*, and *foreign bodies*, embedded in a "transparent, colourless, and structureless matrix." The granules form heaps which are sometimes the $\frac{1}{1000}$th of an inch or more in diameter. The "granule" is a rounded or oval disc, which is stained yellow by iodine, and is dissolved by acetic acid. "The granule heaps *and* the transparent gelatinous matter in which they are embedded represent masses of protoplasm." One of the masses of this deep-sea "urschleim" may be regarded as a new form of the simplest animated beings (*Moner*), and Huxley proposes to call it *Bathybius*.* The "*Discolithi* and the *Cyatholithi*," some of which resemble the "granules," are said to bear the same relation to the protoplasm of *Bathybius* as the spicula of sponges do to the soft parts of those animals; but it must be borne in mind that *the spicula of sponges are imbedded in a matrix, which is formed by and contains, besides the spicula, small masses of living or germinal matter*, which have been ignored, although the matrix is produced and the form of the spicula deter-

* The idea of the existence of huge continuous masses of living matter of enormous extent, is most fanciful and improbable. It appears to be opposed to well ascertained facts. So far from living matter growing to form very large collections, it divides in almost all known instances before it reaches the diameter even of $\frac{1}{500}$ of an inch. I think that the phenomena essential to living matter are only possible in minute masses separated from one another, so that each may be supplied with nutrient materials. *See* "Of Life," p. 67.

mined by them. As in other cases, this matrix, with the living matter included, constitutes "protoplasm."

Bathybius has been fancifully described as "a vast sheet of *living matter* (!) enveloping the *whole earth* beneath the seas," composed of molecules whose organizing tendencies will be shown after the lapse of several thousand years in the Fauna and Flora of the period of which the unscientific cannot now form the remotest conception. But it is surely a consoling thought, and one eminently calculated to confirm our faith in the infallibility of the new philosophy, to remember the remarkable prophecy that the successful neo-biologist is not only to render evident the wonderful properties now dormant in the existing Bathybius, but as soon as he shall have succeeded in demonstrating to us the properties of the molecules which once formed the primitive nebulosity, he will be able to predict the exact state of the Fauna and Flora of Middlesex in the year 5069, and with as much certainty as he can now tell us what will happen if exactly one thousand grains of proteid organic matter be exposed, in an atmosphere of carbonic acid to a temperature of 25° during the space of two hours.

Dr. Wallich's Observations.—Dr. Wallich has, it need scarcely be said, arrived at a very different conclusion. In a paper "On the Vital Functions of the Deep-sea Protozoa," published in No. I. of the "Monthly Microscopical Journal," January, 1869, this observer, who has long been engaged in this and kindred studies, states that the coccoliths and coccospheres stand in no direct relation to the protoplasm substance referred to by Huxley under the name of *Bathybius*. The former are derived from their parent coccospheres,

which are independent structures altogether. "*Bathybius*," instead of being a *widely-extending sheet of living protoplasm* which grows at the expense of inorganic elements, is rather to be regarded as a complex mass of slime with many foreign bodies and the *débris* of living organisms which have passed away. Numerous minute living forms are, however, still found on it.

Dr. Wallich is of opinion that each coccosphere is just as much an independent structure at *Thalassicolla* or *Collosphæra*, and that, as in other cases, "nutrition is effected by a vital act," which enables the organism to extract from the surrounding medium the elements adapted for its nutrition. These are at length converted into its sarcode and shell material. In fact, in these lowest simplest forms, we find evidence of the working of an inherent vital power, and in them nutrition seems to be conducted upon the same principles as in the highest and most complex beings. In all cases the process involves, besides physical and chemical changes, purely *vital actions*, which cannot be imitated, and which cannot be explained by Physics and Chemistry.

Chemistry of Protoplasm.—From what has been said already, it must be obvious that the chemistry of the complex matter now termed protoplasm, embraces, 1, the chemistry of the formed matter, and 2, the chemistry of the active, living, growing, matter, of an organism. By chemical analysis we can ascertain the composition of the first, and can learn many facts concerning its elementary chemical characters; but it is obvious that chemistry can teach us little with regard to the composition of the living matter, for we kill it when we attempt to analyze it; and

in truth we analyze not the *living matter*, but the substances resulting from its death. Of course any one may say that the inanimate substances he obtains were the actual things of which the living matter was composed, but it is a mere assertion, for the bodies in question cannot be detected in the matter *while it is actually alive;* and when obtained they do not possess the properties or powers characteristic of the living matter.* What, therefore, can be gained by asserting that these things constitute living matter? What is the use of trying to make people believe and confess that there is no difference between a living thing and the same thing dead, when it is clearly possible that there may be the very greatest difference?

And I must not omit to notice here a remark made by Mr. Herbert Spencer, which illustrates the extraordinary opinion entertained by him concerning the difference between living, growing, active, matter, and perfectly lifeless matter. "On the other hand (he says) the microscope has traced down organisms to simpler and simpler forms, until, in the *Protogenes* of Professor Hæckel there has been reached a type *distinguishable from a fragment of albumen only by its finely granular character.*"† Mr. Herbert Spencer should prepare a solution of albumen and a solution of "proto-

* "In the last place, Mr. Huxley's analysis is an analysis of *dead* protoplasm, and indecisive, consequently, for that which *lives*. Mr. Huxley betrays sensitiveness in advance of this objection; for he seeks to rise above the sensitiveness and the objection at once by styling the latter 'frivolous.'" "As regards Protoplasm in relation to Professor Huxley's Essay on the Physical Basis of Life," by J. H. Stirling, LL.D., F.R.C.S. Edinburgh, Blackwood and Sons, October, 1869.

† "The Principles of Psychology," p. 137.

genes," and by careful evaporation he might obtain two extracts not distinguishable from one another. Both would exhibit a "finely granular character," and thus the important fact that there was no difference whatever between the inanimate albumen and the inanimate "protogenes" would be demonstrated. And as every one is now prepared to admit that there is no difference between dead "protogenes" and living "protogenes," we must of course accept the conclusion that the lowest forms of life are but forms of albumen. In this way "the chasm between the inorganic and the organic is being filled up!"

"*Properties*" *of Matter.*—Here are some specimens of the dogmatic assertions which have been advanced in place of facts and arguments in favour of the physico-chemical doctrines. "The difference between a crystal of calcspar and amorphous carbonate of lime corresponds to the difference between living matter and the matter which results from its death. Just as by chemical analysis we learn the composition of calc spar, so by chemical analysis we ascertain the composition of living matter. It is not probable that there is any real difference in the nature of the molecular forces which compel the carbonate of lime to assume and retain the crystalline form, and those which cause the albuminoid matter to move and grow, select and form and maintain its particles in a state of incessant motion. The property of crystallising is to crystallisable matter what the vital property is to albuminoid matter (protoplasm). The crystalline form corresponds to the organic form, and its internal structure to tissue structure. Crystalline force being a property of matter,

vital force is but a property of matter." It might be objected that crystalline force keeps particles still and compels them to assume a constant form, while vital force prevents them from assuming any definite form at all and keeps them moving,—*form* being assumed only when the matter is withdrawn from the influence of the vital force; but these and any other objections raised to the physical theory of life are accounted absurd and frivolous. It has been asserted positively that there is but one true theory of life—the physical theory. Its advocates seem to think that any objections raised to this ought not to be listened to, because they assert prophetically that by the rapid advance of molecular physics, the truth of their theory will *some day* be fully established.

Aquosity and Vitality.—The properties possessed by inorganic compounds are supposed to be due in some way to the properties of the elements of which they consist. Thus it has been remarked that the properties of water result from the properties of its constituent gases, and are not due to "aquosity," as if any reasonable man would think of referring the properties of water to such a "subtle influence" as "aquosity." It has been argued that since the properties of water are due to its gases and not to *aquosity*, the properties of protoplasm are due to its elements, Oxygen, Hydrogen, Nitrogen, and Carbon, and not to *vitality*. But the cases are by no means parallel. Of water there is but one kind.* Of protoplasm there are kinds innumerable. The constituent elements of the same particle of water may

* A hostile critic has discovered that there are at least two kinds, dirty water and clean water!

be separated and recombined again and again as many times as we please; but the elements of protoplasm once separated from one another, can never be combined again to form any kind of protoplasm. But further, every kind of protoplasm differs from every other kind most remarkably in the results of its living, one producing man, another dog, a third butterfly, a fourth amœba, and so on. Now, what can be more absurd than to suggest that the properties of man, dog, butterfly, and amœba are due not to vitality, but to the constituent elements, or to the properties of the molecules of their tissues? Do the properties of the elements of dog differ sufficiently from those of the elements of man, to account for the differences between dog and man. Have we not rather reason to infer an approximation towards *identity of composition* in the living matter, with marvellous difference in the results of the vital actions? How, then, can the differences be due to the ordinary properties of the elements? Wonderful properties have indeed to be discovered in connection with elements before we can refer the differences in property of living beings compounded of them to the properties of the elements themselves. The argument advanced against vitality, as far as it rests upon the non-existence of aquosity, is utterly worthless, and it is astonishing that any writer who gave his readers credit for moderate intelligence should have adduced it at all.

To sum up in few words. The term protoplasm has been applied to the viscid nitrogenous substance within the primordial utricle of the vegetable cell and to the threads and filaments formed in this matter; to the primordial

utricle itself; to this and the substances which it encloses; and to all these things, together with the cellulose wall; to the matter composing the sarcode of the foraminifera; to that which constitutes the amœba, white blood-corpuscle, and other naked masses of germinal matter; to the matter between the so-called nucleus and muscular tissue, and to the contractile matter itself; to everything which exhibits contractility; to nerve-fibres, and to other structures possessing remarkable endowments; to the soft matter within an elementary part, as a cell of epithelium; to the hard external part of such a cell; to the entire epithelial cell.

Inanimate albuminous matter has been regarded as protoplasm. Living things have been spoken of as masses of protoplasm; the same things dead have been said to be protoplasm. If the matter be boiled or roasted, it is still protoplasm; and there seems no reason why it should not be dissolved, and yet retain its name protoplasm.

It is therefore very difficult to see what advantage is to be gained by the use of the word "protoplasm." If we call a cell a protoplasm, and an egg a protoplasm, and a sheep a protoplasm, and a man a protoplasm, we do not therefore get a clearer idea of any one of them than we had before, while on the other hand the words cell, egg, sheep, man, are distinctive, short, and generally understood. There would be terrible risk of very different living things being confounded, if they were all called "protoplasms."

Notwithstanding the clever and subtle arguments which have been advanced in its favour, and repeated over and over again in almost every possible form, the new doctrine

of life has exerted very little influence. It is absurd to expect that thoughtful persons will be convinced that vital phenonema are physical and chemical phenomena, simply by an authoritative assertion that they are so; and no matter how energetically the doctrine may be advocated, it will not be received unless it is proved to be founded upon facts. In spite of all that has been said, the chemist has taught us little concerning the nature of the changes which take place when pabulum becomes totally changed and converted into living matter, or when the latter gives rise to some peculiar kind of formed matter. He has shown us, it is true, that certain substances resulting in the organism during the disintegration of formed matter may be prepared artificially in the laboratory; but he knows as well as the physiologist, that their formation in the organism is conducted upon totally different principles, of the nature of which all are entirely ignorant. And it is childish to attempt, as some have done, to hide our ignorance by referring the actions to subtle influences, cell-laboratories, and molecular machinery, when every one knows there is nothing like a laboratory or machinery in any molecule or cell in any organism.

The different forms and properties of living beings can only be explained by supposing the influence of force different from ordinary forces acting upon the matter of which they are composed, or upon the existence of properties, other than the inorganic properties, transmitted or handed down from pre-existing matter having similar, though, perhaps, not identical properties. These *vital properties* seem to be superadded to matter temporarily, and are not, like the former,

permanent endowments. The one class of properties remains permanently attached to the elements of matter; the other may be once removed, but can never be restored. The material properties belong to the matter, whether living or dead; but where are the vital properties in the dead material? If physicists and chemists would restore to life that which is dead, we should all believe in the doctrine they teach. So long as they tell us their investigations only *tend* towards such a consummation, they must expect a few to be wanting in faith.

"You may bury me as you choose, if you can only catch me. But you will not understand me when I tell you that I, Socrates, who am now speaking, shall not remain with you after having drunk the poison, but shall depart to some of the enjoyments of the blest. You must not talk about burying or burning Socrates, as if I were suffering some terrible operation. Such language is inauspicious and depressing to our minds. Keep up your courage and talk only of burying the body of Socrates; conduct the burial as you think best, and most decent."—*Plato, Phædon, p.* 115, *C-D.; Grote's Plato, vol. II., p.* 193.

GERMINAL OR LIVING MATTER, AND FORMED MATTER.

NOTHING that lives is alive in every part. Probably no one would maintain that the shell of an oyster or mussel, for example, was, like the living moving mollusk itself, in a living state. Nevertheless, the shell *grows*, but upon careful examination it will be found that *growth* is restricted to certain points. It grows at the free edge and upon the inner surface, and thus increases in dimensions. By far the greater part of the shell, therefore, is as lifeless while it yet remains connected with the living animal as after it has been preserved in our cabinet. The new matter which is added to it by the living creature is prepared and formed through the instrumentality of living matter. In man, and the higher animals, the free portions of the nails and hair, the outer part of the cuticle, and a portion of the dental tissues, are evidently lifeless. But the waste and removal of some of these is compensated for to a great extent by the addition of new matter by living particles. Of the internal tissues a great part is also in a non-living condition, and it therefore becomes necessary in all inquiries concerning the nature of the changes and actions taking place in living beings, to determine at the outset, what parts of these beings are in a living state, and what

parts have already ceased to live, although they may perform important service of a passive kind, and be connected with the matter that is actually alive. Even in the smallest organisms which exhibit the simplest characters, as well as in every texture of the most highly complex beings, we can demonstrate two kinds of matter, differing in most remarkable particulars from one another; or perhaps it would be more correct to say, matter in two *different states, manifesting different properties* and exhibiting differences in appearance, chemical composition, &c., and physical characters. This distinction is essential and invariable, and although by calling everything entering into the composition of a living being by the same name, all differences of state, structure, and composition may be ignored, these cannot be destroyed; and every one who really desires to learn anything about the structure, growth, and actions of living things will find himself compelled to admit these differences, and will at once proceed to investigate how they are to be accounted for.

In my lectures at the Royal College of Physicians, in the spring of 1860, I demonstrated in the tissues of plants, animals, and man in health and disease, matter in the two different states above referred to, and I showed that every normal and abnormal cell or elemental unit of every tissue capable of growth, or possessing formative power, invariably consisted of matter in these two states or conditions: 1. Living, active, formative; 2. Lifeless, passive, formed. In my preparations these two different forms of matter are at once distinguished, the first being artificially coloured with carmine, while the matter in the last condition remains untinged.

As investigation proceeded, I became more and more convinced of the importance of the distinction I had drawn, and it was proved that the matter coloured, which had been considered by many authors to be of little importance, was really in the living, active, growing state. It was shown that upon it all growth, multiplication, conversion, formation, and, in short, life depends. And in many instances when death occurred, the matter in the first state alone changed, while the last remained unaltered. The first was alone capable of *dying*, for, in fact, this only had been *alive*. On the other hand, the matter in the second condition, although it may possess very remarkable properties, and have a highly complex chemical composition never *grows* or *multiplies*. It never *converts* or *forms*. New matter *may be added* to it, but it cannot convert matter of itself. In short, it does not live.

Lastly, facts and arguments were advanced which showed that all matter in the last or formed state *was once in the first or living state*, so that the properties it acquired and the characters it possessed as formed matter were to be attributed to the changes which had been brought about while the matter existed in the antecedent or living state.

There is reason to think that not even the smallest living particle seen under the 1–50th of an inch objective consists of matter in the same state in every part, for it consists of—1, living matter; 2, matter formed from this; and 3, pabulum, which 1 takes up.

The matter in the first state is alone concerned in *development, and the production of those materials which ultimately take the form of tissue, secretion, deposit, as the case may be.* It alone possesses the power of growth and of producing

matter like itself out of materials differing from it materially in composition, properties, and powers. I therefore called it *germinal* or *living matter*, to distinguish it from the *formed material*, which is in all cases destitute of these properties. The difference between germinal or living matter and the pabulum which nourishes it, on the one hand, and the formed material which is produced by it, on the other, is, I believe, absolute. The pabulum does not shade by imperceptible gradations into the living matter, and this latter into the formed material; but the passage from one state into the other is sudden and abrupt, although there may be much living matter mixed with little lifeless matter or *vice versâ*. The ultimate particles of matter pass from the lifeless into the living state, and from the latter into the dead state, suddenly. Matter cannot be said to *half-live* or *half-die*. It is either *dead* or *living*, *animate* or *inanimate;* and formed matter has ceased to live.

Matter may be more or less perfectly or imperfectly formed, and formed matter may differ in hardness, colour, consistence, and a number of other qualities, and it may gradually pass from one state into the other; but nothing of this kind is observed in the case of the germinal matter. The formed matter may possess very remarkable properties, and may undergo various physical and chemical changes under the influence of heat, moisture, oxygen, &c. It may permit some fluids to permeate it, and may interfere with the passage of others. It may contribute to the stability of the organism, and perform a variety of important functions, but it cannot take the place of the germinal or living matter, nor in many cases does it continue to exhibit its characteristic

properties after the death of the germinal matter belonging to it has occurred.

The terms Living Matter, Formed Matter, and Pabulum.—Since many kinds of formed matter had been called *protoplasm* as well as the matter which is in the living state, I should have been wrong if I had employed that term in speaking of *living matter*. From the time when my researches were made to the present, the confusion in the use of the word protoplasm has continued to increase, until every form of tissue has been thus called, as well as every kind of germinal or living matter. And it would only add to the existing confusion if any attempt were now made again to alter the meaning of the word; so that, upon the whole, it seems better to use the more simple term *living or germinal matter* to denote the growing, active, moving substance which is peculiar to everything living, and which is alone concerned in the multiplication, growth, and formation of all tissues and organisms.

Living or germinal matter, *formed matter*, and *pabulum*, are the only terms required in describing the development, formation, and growth of any tissue, the production of secretions, and other phenomena peculiar to living things; and I have ventured to suggest the use of these terms, because they have the advantage of being simple. They can be accurately defined and distinguished from other terms. They are short, expressive, and can be remembered without difficulty, and there is certainly an absence of that mysteriousness which hangs about so many of our scientific words in ordinary use, and greatly adds to the difficulties experienced by the student.

General Characters of Germinal Matter.—The characters of germinal matter may be studied in the lowest organisms in existence, and in plants, as well as in man and the higher animals. Germinal or living matter is always transparent, colourless, and, as far as can be ascertained by examination with the highest powers, perfectly structureless, and it exhibits these same characters at every period of existence.

The germinal matter of the thallus of the growing sugar fungus exists in considerable quantity, and is well adapted for examination. The growing extremity of the branch is rounded, and here the process of growth is going on with great activity. When the operation of staining has been conducted successfully, these growing extremities are more deeply stained than the rest of the germinal matter. A similar fact is observed if one of the placental tufts is submitted to examination. At the extreme end of each tuft is a mass of germinal matter which is darkly stained by the carmine fluid. Behind this, and growing towards it, is the vascular loop; but as the tufts grow, the mass of formless, structureless germinal matter at the end of each moves onwards, the vessels being developed in its wake. This formless living matter moves forwards and burrows, as it were, into the nutrient pabulum, some of which it takes up as it moves on. It is not *pushed* from behind, but it moves forward of its own accord. In a similar manner the advancing fungus bores its way into the material upon which it feeds, and the root filament insinuates itself into interstices between the particles of the soil. In the hair, the germinal matter grows and multiplies at the base or bulb, pushing the firm and already formed tissue

before it. In the first case, the germinal matter is increasing at the extremity of a filament which it spins behind it as it moves on; in the last, the tissue already formed is *pushed on* by the production of new texture in its rear. The extremity of the hair is its oldest part, and nearest to the root is the tissue which was most recently formed. But whether germinal matter moves on in its entirety, or, advancing from a fixed point, forms a filament, a tube, or other structure which accumulates behind it, or itself remains stationary while the products of formation are forced onwards in one direction, or outwards in all, the nature of the force exerted is the same, and due to the *marvellous power which one part of a living mass possesses of moving in advance of another portion of the same, as may be actually seen to occur in the humble amœba, in the mucus- or in the white blood-corpuscle from man's organism, as well as in the pus corpuscle formed in disease.*

Amœba.—Among the simplest living things known to us are the amœbæ, which might be almost described as animate masses of perfectly transparent moving matter. Amœbæ, fig. 4, pl. II., can be obtained for examination by placing a small fragment of animal or vegetable matter in a little water in a wine-glass, and leaving it in the light part of a warm room for a few days. I have found it convenient to introduce a few filaments of cotton wool into the water. The amœbæ collect amongst the fibres, which prevent them from being crushed by the pressure of the thin glass cover.

The delicate material of which these simple creatures are composed exhibits no indications of actual structure, although it is darker and more granular in some parts than

in others. The germinal matter of all organisms, and of the tissues and organs of each organism, exhibits precisely the same characters. It *lives*, and *grows*, and *forms* in the same way, although the conditions under which the phenomena of life growth and formation are carried on differ very much in different kinds of germinal matter. A temperature at which one kind will live and grow actively will be fatal to many other kinds. So, too, as regards pabulum, —substances which are appropriated by one form of germinal matter will act as a poison to another. But the way in which the germinal matter moves, divides and subdivides, grows, and undergoes conversion into tissue, is the same in all. Many remarkable differences in structure, properties, action, and character, are associated with close similarity, if not actual identity of composition. These must, therefore, be attributed not to properties of elements, physical forces, chemical affinities, or other characters which we can ascertain or estimate by physical examination, but to a difference in *vital power* which is inherited, which we cannot isolate, but which it would be unreasonable to ignore.

On Vital Movements.—One characteristic of every kind of living matter is spontaneous movement. This, unlike the movement of any kind of non-living matter yet discovered, occurs in all directions, and seems to depend upon changes in the matter itself, rather than upon impulses communicated to the particles from without.

I have been able to watch the movements of small amœbæ, which multiplied freely without first reaching the size of the ordinary individuals. I have represented the

appearance under a magnifying power of 5,000 diameters of some of the most minute amœbæ I have been able to discover. (Plate II, fig. 3.) Several of these were less than $\frac{1}{100000}$th of an inch in diameter, and yet were in a state of most active movement. The alteration in form was very rapid, and the different tints in the different parts of the moving mass, resulting from alterations in thickness, were most distinctly observed. The living bodies might, in fact, be described as consisting of minute portions of very transparent material, exhibiting the most active movements in various directions, in every part, and capable of absorbing nutrient materials from the surrounding medium. A portion which was at one moment at the lowest point of the mass would pass in an instant to the highest part. In these movements one part seemed, as it were, to pass through other parts, while the whole mass moved now in one, now in another direction, and movements in different parts of the mass occurred in directions different from that in which the whole was moving. What movements in lifeless matter can be compared with these?

The movements above described continue as long as the external conditions remain favourable; but, if these alter and the amœba be exposed to the influence of unfavourable circumstances—as altered pabulum, cold, &c.—the movements become very slow, and then cease altogether. The organism becomes spherical, and the trace of soft formed material upon the surface increases until a firm protective covering, envelope, or cell-wall results. In this way the life of the germinal matter is preserved until the return of favourable conditions, when the living matter emerges from

its prison, grows, and soon gives rise to a colony of new amœbæ, which exhibit the characteristic movements.

Mucus Corpuscle.—Every one knows that upon the surface of the mucous membrane of the air-passages, even in health, there is a small quantity of a soft viscid matter generally termed *mucus*. This mucus, said to be *secreted* by the mucous membrane, contains certain oval or spherical bodies or corpuscles, which are transparent and granular. From the changes of form which take place in them, it is certain that the matter of which they are composed is almost diffluent. These corpuscles or cells are *mucus corpuscles*, but they have no cell-wall. They are separated from each other by, and are embedded in, a more or less transparent, viscid, tenacious substance formed by the corpuscles, and termed *mucus*. (Plate II, fig. 1.)

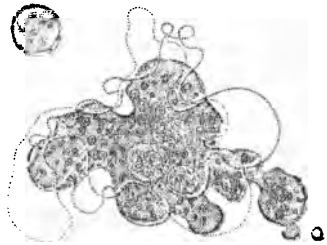
No language could convey a correct idea of the changes which may be seen to take place in the form of the living mucus or pus corpuscle; every part of the substance of a corpuscle exhibits distinct alterations within a few seconds. The material which was in one part may move to another part. Not only does the position of the component particles alter with respect to one another, but it never remains the same. There is no *alternation* of movements. Were it possible to take hundreds of photographs at the briefest intervals, no two would be exactly alike, nor would they exhibit different gradations of the same change; nor is it possible to represent the movements with any degree of accuracy by drawings, because the outline is changing in many parts at the same moment. I have seen an entire corpuscle move onwards in one definite direction for a dis-

GERMINAL OR LIVING MATTER.

Fig. 1.

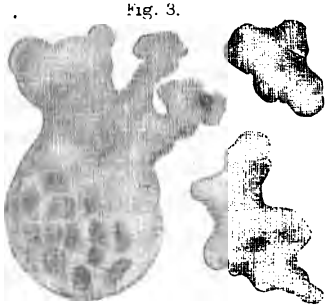
Mucus from the trachea during life, magnified 500 diameters.

Fig. 2.



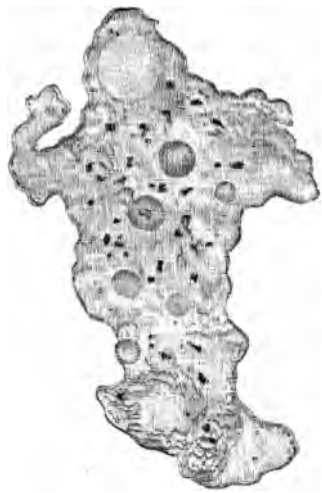
One of the living mucus corpuscles represented in Fig. 1, magnified by the $\frac{1}{50}$ = 800 diameters, showing alterations in form during one minute.

Fig. 3.



Very minute living amæbæ, magnified 800 diameters.

Fig. 4.

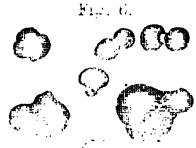


A small amœba magnified by the $\frac{1}{50}$ = 800 diameters.

Fig. 5.

Minute particle of germinal matter from living pus corpuscle, showing the different forms which it assumed in the course of five seconds. × 2800.

Fig. 6.



Particles of germinal matter from vaccine lymph. × 2800.

1000th of an inch [× 2000.

A line five times the length of this will represent the $\frac{1}{1000}$ of an inch

tance equal to its own length or more. Protrusions would occur principally at one end, and the general mass would gradually follow. Again, protrusions would take place in the same direction, and slowly the remainder of the corpuscle would be drawn onwards, until the whole had been removed from the place it originally occupied, and would advance onward for a short distance in the mucus in which it was embedded. From the first protrusions smaller protrusions very often occur, and these gradually become pear-shaped, remaining attached by a narrow stem, and in a few seconds perhaps again become absorbed into the general mass. From time to time, however, some of the small spherical portions are detached from the parent mass, and become independent masses of germinal matter, which grow until they become ordinary mucus corpuscles. (Pl. II, fig. 2.) Are these phenomena, I would ask, at all like any known to occur in lifeless material?

The component particles evidently alter their positions in a most remarkable manner. One particle may move in advance of another, or round another. A portion may move into or round another portion. A bulging may occur at one point of the circumference, or at ten or twenty different points at the same moment. The moving power evidently resides in every particle of a very transparent, invariably colourless, and structureless material. By the very highest powers only an indication of minute spherical particles can be discerned. Because molecules have been seen in some of the masses of moving matter, the motion has been attributed to these. It is true the molecules do move, but the living transparent material in which they are situated

moves first, and the molecules flow into the extended portion. The movements cannot, therefore, be ordinary *molecular movements*. It has been said that the movements may result from diffusion, but what diffusion or other movement with which we are acquainted at all resembles these? Observers have ascribed them to a difference in density of different parts, but who has been able to produce such movements by preparing fluids of different density? But further, in the case of the living matter, these supposed fluids of different density make themselves and retain their differences in density.

Nor is it any explanation of the movements to attribute them to inherent "irritability," unless we can show in what this *irritability* essentially consists. Some dismiss the matter by saying that the movements depend upon the property of "contractility," but the movements of germinal matter are totally distinct from contractility, as manifested by muscular tissue; since they take place in every direction, and every movement differs from the rest, while in muscular contraction there is a constant repetition of changes taking place alternately in directions at right angles to one another; and hence, if the movements in question be due to contractility, it is necessary to assume two very different kinds of contractile property.*

The movements in the mucus corpuscle and in the *amœba*, are of the same nature as those which occur in the germinal matter of many plants, as is easily observed in the cells of the leaves of the vallisneria or the anacharis, in the chara, and in the hairs of the flower of Tradescantia; and the

* See my paper "On Contractility as distinguished from purely vital movements."—"Trans. Mic. Soc." 1866.

appearance of the living matter under very high powers is precisely the same in all cases. Similar movements certainly occur in pus, and in cancer, and probably in every kind of living matter in health and in disease. (Pl. II, figs. 5 and 6.) In some instances the movements continue for many hours after the living matter has been removed from the surface upon which it grew. In other cases, and we shall not be surprised that this should be so in the higher animals, death occurs the instant the conditions under which the living matter exists are but slightly modified. In many instances no movements can be seen, but the evidence of their occurrence is almost as decided as if they were visible, for we discern certain results which can only be explained by the occurrence of such movements as have been referred to.

I have often tried to persuade the physicist, who has so long prophesied the existence of molecular machinery in living beings, to seek for it in the "colourless, structureless," germinal matter. But he contents himself with asserting that such machinery exists, although he cannot see it or make it evident to himself or others.

Of New Centres—Nuclei and Nucleoli.—In many masses of germinal matter a smaller spherical portion often appearing a mere point is observed, and in some cases this divides before the division of the parent mass takes places. This, however, is not necessary to the process, for division takes place in cases in which no such bodies are to be seen, and it frequently happens that one or more of these smaller spots or spherical masses may appear in its substance, *after* a portion of germinal matter has been detached from the parent mass. These are to be regarded

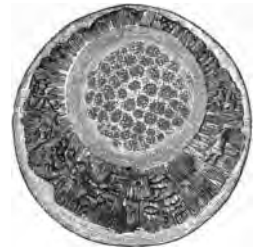
as *new centres* composed of living matter. Within these a second series is sometimes produced. The first have been called *nuclei*, and those within them *nucleoli*. Marvellous powers have been attributed to nuclei and nucleoli, and by many these are supposed to be the agents alone concerned in the process of multiplication and reproduction. Nuclei and nucleoli are always more intensely coloured by alkaline colouring matters than other parts of the living or germinal matter, a fact which is alone sufficient to show the difference between a true nucleus or new centre, and an oil globule, which has often been wrongly termed a nucleolus. I have endeavoured to show that the bodies called nuclei and nucleoli may be regarded as new centres which have arisen in already existing germinal matter. These new centres may be few or very numerous, and there may be many successive series of such centres, each, when it comes to be developed, manifesting powers different from the pre-existing series. And in certain cases it would appear that as this process of formation of new centres, one within the other, proceeds, new powers are acquired, or if we suppose that all possessed the same powers, those masses only which were last produced retain them, and manifest them when placed under favourable conditions. Although nuclei and nucleoli are germinal or living matter, they are not undergoing conversion into formed material. Under certain conditions the nucleus may increase, and exhibit all the phenomena of ordinary germinal matter—new nuclei may be developed within it, new nucleoli within them; so that ordinary germinal matter may become formed material, its nucleus growing larger and taking its place. The original nucleolus

OVA OF THE COMMON STICKLEBACK.
PRODUCTION OF NEW LIVING CENTRES IN PRE-EXISTING LIVING MATTER.

Fig. 7.

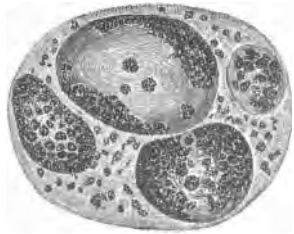
Most minute ovarian ova undergoing development, in the midst of a delicate tissue composed of cells. Magnified 500 diameters.

Fig. 8.



Ovarian ovum, with large germinal vesicle. The yolk cracked and exhibiting fissures radiating outwards. Magnified 100 diameters.

Fig. 9.



Germinal spots from a ruptured germinal vesicle. × 350. The ovum was $\frac{1}{25}$ inch in diameter, and the germinal vesicle $\frac{1}{250}$.

Fig. 10.

Extremely small germinal spots, with new centres within them. × 700.

Fig. 11.

Germinal spots, with new centres (nucleoli) within them, and more minute germinal spots in the intervals between them. × 350.

[illegible]th of an inch. × 215.

[illegible] × 350.

[illegible] × 1700.

now becomes the nucleus, and new nucleoli make their appearance in what was the original nucleolus. The whole process consists of evolution from centres, and the production of new centres within pre-existing centres. Zones of colour, of different intensity, are often observed in a cell coloured with carmine; the outermost or oldest, or that part which is losing its vital powers, and becoming converted into formed material, being very slightly coloured,—the most central part, or the nucleus, *although furthest from the colouring solution*, exhibiting the greatest intensity of colour. These points are illustrated in Pl. VI, fig. 19, and some other figures.

Germinal matter, in a comparatively quiescent state is not unfrequently entirely destitute of nuclei, but these bodies sometimes make their appearance if the mass be more freely supplied with nutrient matter. This fact may be noticed in the case of the connective tissue corpuscles, and the masses of germinal matter connected with the walls of vessels, nerves, muscular tissue, epithelium, &c., which often exhibit no nuclei (or according to some, nucleoli), but soon after these tissues become supplied with an increased quantity of pabulum, several small nuclei make their appearance in all parts of the germinal matter. (Pl. VIII, fig. 36.)

So far from nuclei being formed *first* and the other elements of the cell *deposited around them*, they make their appearance in the substance of a pre-existing mass of germinal matter, as has been already stated. The true nucleus and nucleolus are not composed of special constituents differing from the germinal matter, nor do they perform any special operations. Small oil-globules, which

invariably result from post-mortem changes in any germinal matter, have often been mistaken for nuclei and nucleoli, but these terms if employed at all should be restricted to the minute masses of germinal matter referred to.

THE CELL, OR ELEMENTARY PART.

The living matter, with the formed matter upon its surface, whatever may be the structure, properties, and consistence of the latter, is *the anatomical unit, the elementary part or cell.* This may form the entire organism, in which case, it must be regarded as a complete individual. Millions of such elementary parts or cells are combined to form every tissue and organ of man and the higher animals. However much organisms and tissues in their fully formed state may vary as regards the character, properties, and composition of the formed material, all were first in the condition of *clear, transparent, structureless, formless* living matter.

Every *growing* cell, and every cell *capable of growth,* contains *germinal matter.* The young cell seems to consist almost entirely of this living material—a fact well observed in a specimen of cuticle from the young frog, which may be contrasted with more advanced cuticle from the same animal. In the mature cells only a small mass of germinal matter (usually termed the nucleus) remains.

In the fully formed fat cell there is so little germinal matter left, that it may be easily be overlooked. In disease, on the other hand, the germinal matter may increase to three or four times its ordinary amount, when it becomes a very striking object. The ovum at an early period of its

development is but a naked mass of germinal matter, without a cell wall, but having a new centre and often numerous new centres (known as germinal spots or nuclei) embedded in it, enclosed in a capsule of formed material "cell wall."*

The mode of formation of the cell, or elemental unit, as well as the origin from it of other units, is well illustrated in the formation of the ovum. In Pl. III, fig 7, the cells constituting the tissue of the ovary of the common stickleback are represented, and amongst them are seen true ova at a very early period of development. The youngest of these differs but little from the cells amongst which it lies. It is, in fact, but one of these which has advanced in development beyond the rest. In fig. 8, a small but complete ovum is seen with its germinal, or living matter, here called germinal vesicle, surrounded by the yolk which consists of formed matter. In the germinal matter are seen numerous germinal spots, which are new living centres of growth originating in living matter. In these are new centres, figs. 9, 10, 11, and in these last others would have appeared at a later period. In all cases the lifeless nutrient material must pass into the very centre of the living particles, before the peculiar *vital* properties are communicated to it.

On the Production of Formed Material.—The processes of growth and increase, as they occur in the tissues of all

* The cell wall (Huxley's "periplastic substance," regarded by him as active and formative) is perfectly passive, while the germinal matter (Huxley's endoplast of 1853, considered by him as unimportant) is the really active and the only living matter of the cell. It is very strange that Mr. Huxley should have so completely modified his views upon this fundamental question, as he has done, without having offered one word in explanation.

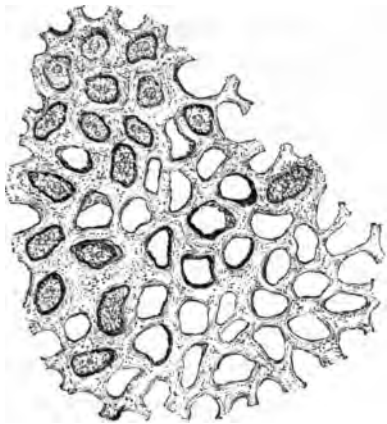
fully-formed living beings, may be well studied in the simple tissue which forms the external covering of the body, and is prolonged in a modified form into the internal cavities. If a thin section be made perpendicularly through this, down to the tissue which contains the nerves and blood-vessels upon which it rests, the appearances represented in Pl. IV, fig. 12, will be observed.

In the first place, it will be remarked that in equal bulks of the tissue there is a larger quantity of germinal matter in the lower part, *a*, which is close to the vessels, than in the upper part, *c*, which is a long distance from the nutrient surface, and that the converse is the case as regards the formed material which gives to this tissue its properties and physical characters. Secondly, it will be noticed that the individual masses of germinal matter increase in size till they arrive at about half way towards the surface, *b*, while from this point to the surface they diminish, *c;* and thirdly, that the distance between them increases on account of the increased formation and accumulation of formed material. By the time the cells have reached the surface, the distance between the masses of germinal matter is reduced again, by the drying and condensation of the formed material.

The changes which each individual cell or anatomical unit passes through may now be considered. At the deep aspect near the nutrient surface are masses of germinal matter embedded in a soft, mucus-like, and, as yet, continuous formed material, *a*. The masses of germinal matter divide, and each of the resulting masses becomes invested with a thin layer of the mucus-like matter. In this way, the elementary parts or cells multiply in number, to compensate for

EPITHELIAL CELLS AND CARTILAGE, SHOWING FORMED MATERIAL IN THE TWO TISSUES RESPECTIVELY AND THE MODE OF ITS FORMATION.

Fig. 13.

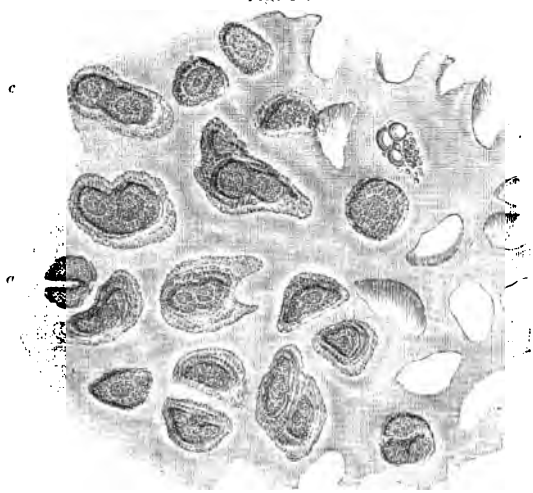


Youngest epithelium from the deep layer of the conjunctiva (the membrane covering the front of the eye) of a cat, showing the formed material continuous and not yet separated into portions corresponding to each mass of germinal matter. Here there are no separate cells. × 600.

Fig. 14.

Superficial or older cells, from the same specimen as Fig. 13, showing formed material belonging to each mass of germinal matter, giving rise to the appearance of separate cells. × 600.

Fig. 15.



A very thin section of cartilage (sternum) of a young newt, showing masses of germinal matter, some of which are dividing, at *a*, *b*, *c*; with formed material, which is continuous throughout as in young epithelium. Figs. 12, at *a*, Fig. 14, p. 61. × 600.

1000th of an inch [illegible] × 350.

the loss of those old cells which are gradually removed from the surface.* Each mass of germinal matter increases in size by the absorption of nutrient pabulum, which, as in all other cases, passes through the layer of formed material. But at the same time, a portion of the germinal matter undergoes conversion into formed material, which accumulates upon the surface within that already formed, and as each new layer is deposited upon the surface of the germinal matter, those layers of formed material already produced are stretched, and with them the last developed are more or less incorporated. (Pl. VIII, fig. 28, p. 60.) For a time, the germinal matter increases, while new-formed material is being produced. In other words, both the constituent parts of the entire cell increase in amount up to a certain period of its life. (Pl. IV, *b*.) But as new cells continue to be produced below, those already formed are gradually removed farther and farther from the vascular surface, while at the same time their formed material becomes more condensed and less permeable to nutrient matter. From this point, each entire cell ceases to increase in size, while the germinal matter actually diminishes, because it undergoes conversion into formed material; at the same time, owing to the increased density of the formed material, and its greater distance from the vessels, little new pabulum is taken up to compensate for this.

* The description here given is not strictly accurate, inasmuch as the new masses of germinal matter do not *all* move in a direction *towards* the surface. Some tend in the opposite direction, towards the subcuticular tissue, but this need not be discussed here, as it would complicate the description without helping in any way to elucidate the question now being considered.

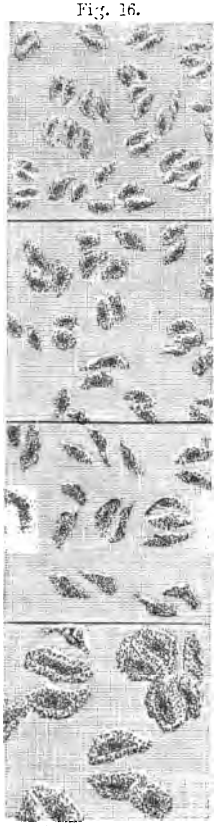
The germinal matter (nucleus) becomes smaller as the cell advances in age. So that it is possible to judge of the age of a cell, irrespective of its size, by the relative amount of its component substances. In old cells, there is much formed material in proportion to the germinal matter, while young cells seem to be composed almost entirely of the latter substance. In very old cells, the small portion of germinal matter still unconverted into formed material, dies, and the cell having by this time arrived at the surface, is cast off,—a mass of perfectly passive, lifeless, formed material.

The facts here described are illustrated in the figure represented in Pl. IV, p. 48, which should be carefully studied.

Of the so-called Intercellular Substance.—In cartilage and some other tissues, there is no line of separation between the portion of formed material which belongs to each mass of germinal matter, as is the case in epithelium, but the formed material throughout the entire tissue forms an uninterrupted mass of tissue, matrix, or, as it has been termed, connective substance. (Pl. V, fig. 15). From the apparent essential difference in structure, it has been supposed that tissues of this character were developed upon a principle very different to that upon which epithelial structures were produced. It has been maintained by some that in cartilage a cell wall, distinct from the intervening transparent material, existed around each cell, and it has been very generally concluded that the matrix was deposited between the cells, and hence this was called "*inter*-cellular substance." But it must not be supposed that epithelium is in all cases to be distinguished from cartilage by the existence of separate cells. In many forms of epi-

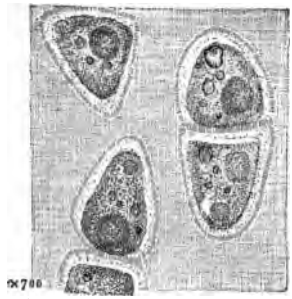
CARTILAGE SHOWING MODE OF PRODUCTION OF FORMED MATERIAL.

Fig. 16.



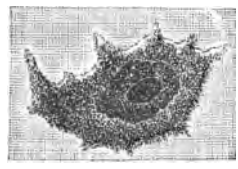
Cartilage at different ages. *a*, young embryo; *b*, six weeks old; *c*, nearly full grown; *d*, adult cat. × 700. Showing alternation in the relative proportions of germinal matter and formed material at different ages.

Fig. 17.



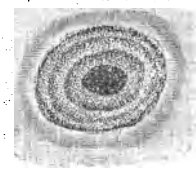
Cartilage, frog; showing germinal matter and formed material. × 700.

Fig. 18.



Young cartilage, kitten, showing the appearances of the germinal matter with the formed material into which it is undergoing conversion. × 180.

Fig. 20.



Cartilage, frog, showing germinal matter about to undergo conversion into formed material.

Fig. 19.

Fig. 21.

Fig. 22.

These figures show the actual conversion of the germinal matter of cartilage into the formed material of that tissue. In 2 and 22 a piece of cartilage has been formed in the very centre of the germinal matter. What is now formed material and lifeless, was a short time previously, germinal matter and living. × 700.

[illegible] × 700.

thelium at an early period of formation, the formed material corresponding to the several masses of germinal matter is continuous throughout, and presents no indications of division into separate cells. This is well seen in the lower part of the specimen represented in Pl. IV, but in fig. 13, Pl. V, an unusually striking example is given. The specimen was taken from the deeper portion of the conjunctival epithelium of man. Not only is there no indication of division into distinct cells, but the structure would be described as a matrix exhibiting spaces occupied by the masses of germinal matter. The arrangement exactly corresponds with that existing in the case of cartilage, and the masses of germinal matter with a thin investment of formed material may be removed just as in that tissue. It is, therefore, clearly erroneous to consider cartilage and epithelium as representatives of different *classes* of tissues. The analogy between them will be at once understood by a glance at fig. 13, and fig. 15, which have been carefully copied from actual specimens. In fig. 14, a portion of older epithelium from the same surface is represented. In this, each mass of germinal matter is invested with its own layers of formed material, and these are distinct from neighbouring portions. A "cell," or elementary part of fully-formed cartilage and tendon, consists of a mass of germinal matter, with a proportion of formed material around it. A line passing midway between the several masses of germinal matter would mark roughly the limit of the formed material, corresponding to each particular mass of germinal matter, and this would correspond with the outer part of the surface or boundary of the epithelial cell.

In order to understand the true relation of the so-called intercellular substance of cartilage or tendon to the masses of germinal matter, it is necessary to study the tissue at different ages. At an early period of development, these tissues appear to consist of masses of germinal matter only. As development advances, the formed material increases, and the masses of germinal matter become separated farther and farther from one another. (Pl. VI, fig. 16.) The appearances of a cell wall around the germinal matter in the fully-formed tissue, and other alterations which occur, and anomalous appearances which often result as age advances, can be even more readily understood upon the view here advanced, than upon the intercellular-substance theory which has been so strongly supported by some observers. *See* Pl. VI, figs. 16 to 22.

Of the Formation of the Contractile Tissue of Muscle.— A muscle "cell," or elementary part, will consist, like that of cartilage and tendon, of the so-called nucleus, with a portion of the muscular tissue corresponding to it. In general arrangement it closely resembles what is seen in tendon. The contractile material of muscle may be shown to be continuous with the germinal matter, and oftentimes a thin filament of the transversely striated tissue may be detached with the oval mass of germinal matter still connected with it, showing that, as in tendon, the germinal matter passes uninterruptedly into the formed material. This contractile tissue is not, like the germinal matter which produced it, in a *living* state. In the formation of the contractile tissue, the germinal matter seems to move onwards, and at its posterior part gradually under-

goes conversion into the tissue. At the same time it absorbs nutrient material, and thus, although a vast amount of contractile tissue may have been produced, the germinal matter which formed it may not have altered in bulk. (Pl. VII, fig. 25.) The fibres of yellow elastic tissue are formed in the same manner, and each fibre is thickened by the formation of new material from germinal matter, which lies upon the external surface of each fibre (fig. 26.).

The Formation of Nerve Fibres.—The nerve fibre is composed of formed material, which is structurally continuous with the formed material of the nerve cells of the nerve centres. A nerve fibre at an early period of development consists of a number of oval masses of germinal matter linearly arranged. As development proceeds, these become separated farther and farther from one another, and the non-living *tissue* which is thus spun off as they become separated, is the nerve. (Pl. VII, fig. 27.)

What is essential to the Cell?—All that is essential to the cell or elementary part is *matter that is in the living* state—*germinal matter*, and matter that *has been in the living state—formed material.* With these is usually associated a certain proportion of matter about to become living—the pabulum or food. So that we may say that in every living thing we have matter in three different states—matter about to become living, matter actually living, and matter that has lived. The last, like the first, is non-living, but unlike this it *has been* in the living state, and has had impressed upon it certain characters which it could not have acquired in any other way. By these characters we know that it has lived, for we can no more

cause matter artificially to exhibit the characters of the dried leaf, the lifeless wood, shell, bone, hair, or other tissue, than we can make living matter itself in our laboratories.

Cells are not like Bricks in a Wall.—Cells forming a tissue have been compared with bricks in a wall, but the cells are not like bricks, they have not the same constitution in every part, nor are they made first and then embedded in the mortar. Each brick of the natural wall grows of itself, places itself in position, forms and embeds itself in the mortar of its own making. The whole wall grows in every part, and while growing may throw out bastions which grow and adapt themselves perfectly to the altering structure. Even now it is argued by some that because things, like fully formed cells, may be made artificially, the actual cells are formed in the same sort of way—an argument as forcible as would be that of a person, who after a visit to Madame Tussaud's Exhibition, seriously maintained that our textures were constructed upon the same plan as the "life-like" wax figures he had seen there.

Every one who really studies the elementary parts of tissues and investigates the changes which occur as the germinal matter passes through various stages of change until the fully developed structure results, will be careful not to accept without due consideration the vague generalisations of those who persist in authoritatively declaring that the changes occurring in cell growth are merely mechanical and chemical, although they are unable to produce by any means at their disposal a particle of fibrine, a piece of cartilage, or even a fragment of coral. They avoid the difficulty

as regards the germinal matter by ignoring its existence, and attribute to a "molecular machinery" which the mind cannot conceive, and which cannot be rendered evident to the senses, all those wonderful phenomena which are really due to vital power. Moreover, resemblances to living organisms of the most fanciful kind are adduced apparently for the purpose of leading people to believe that non-living matter behaves like that which is alive.*

On the Nutrition of a Living Cell.—In nutrition, the active changes are exclusively confined to the germinal matter. The formed material is passive, and probably acts like a filter, permitting some things to pass and interfering with the passage of others. In nutrition, pabulum becomes germinal matter to compensate for the germinal matter which has been converted into formed material. Now let us consider the order of these changes, and endeavour to express them in the simplest possible manner.

Let the germinal matter which *came from pre-existing germinal matter* be called *a;* the non-living pabulum, some

* Professor Tyndall describes ("Proceedings of the Royal Society," vol. xvii, No. 105) the changes resulting from the influence of light on the vapour of an aqueous solution of hydriodic acid. His rhapsodical description, which extends over an entire page, contains the following curious allusions and comparisons:—A cloud was developed like an organism from a formless mass to a marvellously complex structure; spectral cones with filmy drapery; exquisite vases with the faintest clouds, like spectral sheets of liquid, falling over their edges; clouds like roses, tulips, sunflowers, and bottles one within the other; a cloud like a fish, with eyes, gills, and feelers, and like a jelly fish, with the internal economy of a highly complex organism, exhibiting the twoness of the animal form; as perfect as if it had been turned in a lathe; and likely to prove exceedingly valuable to pattern designers!

of the elements of which are about to be converted into germinal matter, shall be *b*; and the non-living formed material resulting from changes in the germinal matter, *c*.

It is to be remarked that *b* does not contain *c* in solution, neither can *c* be made out of *b* unless *b* first passes through the condition *a*, and *a* cannot be formed artificially, but must come from pre-existing *a*.

In all cases *b* is transformed by *a* into *a*, and *a* undergoes conversion into *c*. Can anything be more unlike chemical and physical change? Neither *a*, nor *b*, nor *c* can be made by the chemist; nor if you give him *b* can he make *a* or *c* out of it; nor can he tell you anything about the "molecular condition" or chemical constitution of *a*, for the instant he commences his analysis *a* has ceased to be *a*, and he is merely dealing with products resulting from the death of *a*, not with the actual living *a* itself. The course which the pabulum takes in the nutrition of the germinal matter of a cell is represented by the arrows in fig. 23, pl. VII.

The nature of the process of nutrition is more fully discussed towards the end of the next section, "OF LIFE."

Of the Increase of Cells.—Several distinct modes of cell increase or multiplication have been described, but in all cases the process depends upon the germinal matter only. It is this which divides; and it is the only part of the cell which is actively concerned in the process of multiplication. It may divide into two or more equal portions, or give off many buds or offsets, each of which grows as a separate body as soon as it is detached. (Pl. VIII.)

The formed material of the cell is perfectly passive in

the process of increase and multiplication. Even the apparently very active contractile tissue of muscle has no capacity for increase or formation. If soft or diffluent, a portion of the formed material may collect around each of the masses into which the germinal matter has divided, but it does not grow in or move in and form a partition, as has often been stated. When a septum or partition exists, it results not from "growing in," but it is simply produced by a portion of the germinal matter undergoing conversion into formed material of which the partition is composed. (Pl. V, fig. 15 *a* and *b*.)

Of the Changes in the Cell in Disease.—I have endeavoured to show that of the different constituents of the fully formed cell, the germinal matter is alone concerned in all active change. This is in fact the only portion of the cell which *lives*, while at an early period of development, some of the structures usually regarded as essential to cell existence are altogether absent, and the cell is but a mass of germinal matter. But it must be borne in mind that at all periods of life, in certain parts of the textures and organs, and in the nutrient fluids, are masses of germinal matter, destitute of any cell-wall, and exactly resembling those of which at an early period the embryo is entirely composed. White blood and lymph corpuscles, chyle corpuscles, many of the corpuscles in the spleen, thymus and thyroid, corpuscles in the solitary glands, in the villi, some of those upon the surface of mucous membranes, some in connection with muscle, nerve, bone, cartilage, and some other tissues, are of this nature, and consist of living germinal matter, with mere traces of soft formed

material around each mass. There is no structure through which these soft living particles, or small portions of living matter detached from them, may not make their way. The destruction of tissue may be very quickly effected by the growth and multiplication of such masses of germinal matter. Many of the changes in disease result from the undue growth of this substance, and indeed there is no operation peculiar to living beings in which germinal or living matter does not take part. Any sketch of the structure of the cell would be incomplete without an account of some of the essential alterations which occur in it in disease. I propose, therefore, to refer very briefly to the general nature of some of the most important morbid changes.

Within certain limits, the conditions under which cells ordinarily live may be modified without any departure from the healthy state, but if the conditions be very considerably changed, *disease* may result, or the cell may die. For instance, if cells, which in their normal state grow slowly, be supplied with an excess of nutrient pabulum, and increase in number very quickly, a *morbid* state is engendered. Or if, on the other hand, the rate at which multiplication takes place be reduced in consequence of an insufficient supply of nourishment, or from other causes, a diseased state may result. So that, in the great majority of cases, *disease* or the *morbid state* essentially differs from health or the healthy state in an increased or reduced rate of growth and multiplication of the germinal matter of one or more particular tissues or organs. In the process of *inflammation*, in the formation of *inflammatory products*, as *lymph and pus*, in the production of *tubercle* and *cancer*, we see the results of in-

creased multiplication of the germinal matter of the tissues or of the germinal matter derived from the blood, consequent upon the appropriation of *excess of nutrient pabulum.* In the shrinking, and hardening, and wasting which occur in many tissues and organs in disease, we see the effects of the germinal matter of a texture being supplied with too little nutrient pabulum, in consequence sometimes of an alteration in the pabulum itself, sometimes of an undue thickening and condensation of the tissue which forms the permeable septum, which intervenes between the pabulum and the germinal matter.

The above observations may be illustrated by reference to what takes place when pus is formed from an epithelial cell, in which the nutrition of the germinal matter, and consequently its rate of growth, is much increased. And the changes which occur in the liver cell in cases of wasting and contraction of that organ (*cirrhosis*) may be advanced as an illustration of a disease which consists essentially in the occurrence of changes at a slower rate than would be the case in the normal condition, consequent upon the normal access of pabulum to the germinal matter being interfered with.

The outer hardened formed material of an epithelial cell may be torn or ruptured mechanically, as in a scratch or prick by insects (Pl. VIII, figs. 32 to 35); or it may be rendered soft and more permeable to nutrient pabulum by the action of certain fluids which bathe it. In either case it is clear that *the access of pabulum to the germinal matter must be facilitated*, and the latter necessarily "*grows*"—that is, converts certain of the constituents of the pabulum that

come into contact with it into matter like itself—at an increased rate. The mass of germinal matter increases in size, and soon begins to divide into smaller portions, fig. 33. Parts seem to move away from the general mass, fig. 34. These at length become detached, and thus several separate masses of germinal matter, which are embedded in the softened and altered formed material, result, figs. 34, 35. These changes will be understood by reference to the figures in Plate VIII. In this way the so-called inflammatory product *pus* results. The abnormal pus-corpuscle is produced from the *germinal or living matter of a normal epithelial or other cell, or elementary part, the germinal matter of which has been supplied with pabulum much more freely than in the normal state.* In all forms of inflammation, the germinal matter of the parts inflamed increases very much, and the same change occurs in every kind of fever, fig. 36, pl. VIII, but not proceed to the same extent. In both conditions there is increased development of heat due to the increase of the germinal matter. Inflammations and fevers are so very closely related that an inflammation may be spoken of as a *local fever*, and a fever as a *general inflammation.*

It will be seen how easily the nature of the changes occurring in cells in inflammation, fever, and other morbid changes, can be explained, if the artificial terms, *cell-wall, cell-contents, nucleus*, be given up. In all acute internal inflammations and in fevers a much larger quantity of inanimate pabulum is taken up by certain cells and converted into germinal matter than in the normal state. Hence there is, at least in the parts affected, increase in

bulk. Cells of particular organs, which live very slowly in health, live very fast in certain forms of disease. More pabulum reaches them, and they grow more rapidly in consequence.

It is by this process of increased multiplication and reproduction of certain kinds of germinal matter of the organism, under altered conditions, that the germs which constitute the material particles of contagious diseases result. These living particles (contagium) having acquired during multiplication new and peculiar properties not possessed by the germinal matter from which they originally sprung, retain these properties and reproduce their kind a million fold whenever placed under conditions favourable to the process, though the operation may be fatal to the organism in which it occurs.

In cells which have been growing very rapidly and are returning to their normal condition, *in which the access of nutrient pabulum is more restricted than in the abnormal state,* as is also the case in normal cells passing from the embryonic to the fully-formed state, the outer part of the germinal matter undergoes conversion into formed material, and this last increases although the supply of pabulum is reduced.

From these observations it follows that disease may result in two ways—either from the cells of an organ growing and multiplying faster than in the normal state, or from their doing so more slowly. In the one case, *the normal restrictions under which growth takes places are diminished; in the other, the restrictions are greatly increased. Pneumonia,* or inflammation of the lung, may be adduced as a striking

example of the first condition, for in this disease millions of minute masses of germinal matter which have escaped from the blood suspended in liquor sanguinis (exudation) grow and multiply very rapidly in the air cells of the lung, and nutrient constituents are diverted from other parts of the body to this focus of morbid activity. Contraction and condensation of the liver, kidney, and other glands, hardening, shrinking, and wasting of the muscular, nervous, and other tissues, are good examples of the second. The amount of change becomes less and less as the morbid state advances, the whole organ wastes, the secreting structure shrinks, and at last inactive connective tissue alone marks the seat where most active and energetic changes once occurred. It is easy to see how such a substance as alcohol must tend to restrict the rapid multiplication of the cells when the process is too active, and how it would tend to promote the advance of disease in organs where rapid change in the cells characterizes the normal state.

These considerations lead us to conclude that the rate of growth of cells in disease may be accelerated or retarded by an alteration in the character of the pabulum which is transmitted to them, and with the view of influencing these changes we shall naturally search for remedies which have the property of rendering tissues more or less permeable to nutrient fluids, or which alter the character of the fluid itself. Such considerations have a very important bearing upon the practical treatment of disease.

Many of the so-called tonics have the property of coagulating albuminous fluids and solutions of extractive matters. Preparations containing tannin, the mineral salts,

such as the sulphate and sesquichloride of iron, nitric and hydrochloric acids, and a host of other remedies that will occur to every one, possess this property, and render solutions containing these and allied substances less permeable, perhaps by increasing their viscidity. The favourable action of such remedies is probably due to their direct influence on the fluid constituents of the blood. They, no doubt, also reduce the rate at which blood-corpuscles are disintegrated, and at the same time they tend to render the walls of the blood-vessels less permeable to fluids.

But, of all remedies, I believe alcohol acts most rapidly in this way, and in these particular cases most efficiently. The properties alcohol possesses of hardening animal tissues, and of coagulating albuminous fluids, are well known; and these properties must not be forgotten when its effects in the animal body are discussed. Of course, when absorbed by the blood, it does not actually coagulate the albuminous matters; but it probably renders them less fluid, and reduces their permeating property. It prevents the growth and multiplication of germinal matter and probably interferes with the multiplication of white blood corpuscles. Alcohol also tends to prevent the disintegration of red blood-corpuscles; and in cases where this is going on very rapidly, and where fluid is passing through the walls of the vessels in considerable quantity, in consequence of the walls themselves being stretched and too readily permeable to fluids, alcohol is likely to be of service; but where these changes are occurring very rapidly, and the patient's strength is fast ebbing, it may save life.

Alkalies, on the other hand, tend to render formed

material more permeable to fluids, and thus facilitate the access of pabulum to the germinal matter. They are often useful in cases where there is shrinking and wasting of textures which in the normal condition consist principally of germinal matter. Potash, soda, lithia, and their carbonates, as well as the salts of many vegetable acids which become converted into carbonates in the system, act beneficially in this way, as well as by producing favourable changes of other kinds.

OF "LIFE."

WHAT is to be understood by the term *life:* is a question which has been answered very differently by different authorities in these days, and it is one to which a satisfactory reply has never yet been received. Few words are in more frequent use, and yet it is most difficult to define the meaning of this word *life*, partly no doubt, because it has been used in so many different senses. By the "life" of the world, of a nation, or of a society, we mean something very different from what we mean by the "life" of an individual; for may not many individuals perish without the life of the world, of a nation, or of a society being destroyed or impaired? The "life" of a man, or an animal, is very different from what is termed the "life" of a white blood, or of a mucus, or pus corpuscle; inasmuch as many hundreds of white blood corpuscles, or elemental units of the tissues, might die in the man, without affecting the "life" of the man; moreover the man himself might perish, and some of the corpuscles remain alive.

"Life," as employed in the first instance, comprises a great number of results and changes so complicated, and so different from one another, that volumes might be written without the subject being exhausted. The "life" of a man or an animal includes phenomena of *essentially different kinds*, some being *mechanical* and *chemical*, while others belong to a

totally different category. Physical and chemical actions may be investigated in many ways, but as far as we can judge, the last class of actions (vital) seems to be beyond investigation, and has not yet been satisfactorily accounted for. If we regard the life of a man, as the sum of all the actions going on in his body, as some are inclined to do, the sum will be made up of a number of very different and heterogeneous items. To sum up these together and express the result in a common total would be as unmeaning as it would be to add ounces to shillings and inches. By the "life" of a white blood corpuscle or other small mass of living matter we mean the property or power or conditions to which the phenomena, characteristic of this and other kinds of matter in the same state, are referable.

Here then are three distinct senses in which the term life has been employed, and more might be adduced. It must, therefore, be obvious that by the *life* of a man something very different is understood from what is meant by the life of each elemental unit of his organism, and the difference is not merely of degree but of kind.

We cannot prove that life results from, or is invariably associated with such and such chemical and physical changes, or is due to certain external conditions, and it is easy to adduce instances in which life is present under opposite and conflicting circumstances. In short the conditions under which life exists are so many and so variable that it is not reasonable to attribute it to any conceivable combinations of external circumstances unless we may assume that the very same phenomena result from the concurrence of very different conditions.

Non-living Particles of Matter contrasted with Living Particles.—It is desirable to consider in this place whether anything may be learnt by comparing very minute lifeless particles with very minute living particles under very high magnifying powers.

A little inorganic matter of any kind, but in a state of very minute subdivision may be subjected to examination. Take for example a little of the deposit of phosphate of lime which has been precipitated from a solution of a salt of lime by the addition of a soluble salt of phosphoric acid. Now what is observed when this fine precipitate is placed under the microscope? Only a number of minute granules or dots possessing no definite form and exhibiting no indications of structure. If the deposit be examined by the highest powers at our command, the apparent size of the particles will indeed be increased, and others which were previously invisible will be brought into view but no appearance of structure can be recognized. Spots they appeared under moderately high powers, and mere spots they remain under the highest magnifying powers we can obtain. Certain *movements* are however to be observed. Each little particle revolves and oscillates in the fluid. These movements have been termed *molecular*, and were first described many years ago by Robert Brown. We know that the particles under observation are inorganic, and we are therefore quite sure that the movements we witness are due to physical forces alone.

Next let us take a small fragment of dead animal or vegetable matter, and place it in a few drops of pure water on a glass slide, and examine carefully the fluid under the

microscope. The water appears as clear and transparent as the glass on which it rests. Both slides may now be placed in a warm room under the same conditions for a few hours, taking care that light and air have free access to both specimens, and that any fluid lost by evaporation be supplied. At the end of five or six hours the slides may again be examined.

The one containing the inorganic deposit of phosphate of lime shall be called A. No change has taken place. There are the little lifeless particles still moving as before in the fluid in which they are suspended. Some of them indeed may have become aggregated together so as to form little collections, but beyond this there appears to have been no change.

Next let the other slide B be examined. The fluid which, when first seen, was perfectly clear, now contains a number of exceedingly minute dots, points, or granules, closely resembling those of the phosphate of lime, and these manifest similar *molecular movements*. If a little gum, glycerine, or any viscid material be added to the particles on each slide, the molecular movements are immediately suspended, and if the fluid be diluted they recur. This indicates that in both cases the movements are due to physical causes. The little particles which could move freely in such a limpid fluid as water, are prevented from moving if the fluid in which they are suspended be rendered viscid.

Let both slides be again set aside for a few hours longer. It will be found that the inorganic matter upon the slide A has undergone no change. But the case is very different with regard to B. The granules that have appeared in the

fluid,—*precipitated* as some would say—have increased vastly in number. Many of them have become altered, or their place has been taken by little bodies, some of which have a circular while others exhibit an elongated oval form; all are perfectly transparent. If, again another interval of time be permitted to elapse, and the slide B is again examined, it will be found that further change has taken place. The little bodies have become larger; in fact they have *grown*, and have moreover increased considerably in number. The *growth* has not resulted from the aggregation and fusion of several particles, as some have surmised, but individual particles have increased in size without absorbing their neighbours. Careful study will now convince the observer that in the case of the largest particles, the central portion differs from the external covering; in fact each particle is composed of *at least two kinds of matter, or matter in two different states.*

The changes described are characteristic of living particles. Repeated experiments have proved that the conditions under which slide B was placed were favourable to the developement of certain simple living organisms. At a certain period the granules on the two slides were scarcely to be distinguished; but while those on A remained unaltered—retained the same granular form in which they were deposited—the particles on B have not been stationary for a moment. They have *grown* into definite though apparently simple forms of matter, which still continue to manifest active changes. In all cases life is associated with never-ceasing change.

Now, the question arises, whence have the *living*

organisms been derived? The water which was examined at first appeared perfectly clear, but now it is filled with living beings. How did they come there? It has been stated that simple organisms such as these may spring up spontaneously; but this statement may be met by very serious objections, if, indeed, it is not contradicted by facts open to the observation of all. The doctrine of spontaneous generation has again quite recently been revived in France, and of course has been again refuted by an overwhelming mass of evidence. It has been proved that if dead animal or vegetable matter be dried, and so placed that the admission of atmospheric air which has passed through strong sulphuric acid or liquor potassæ is alone admitted, organisms will nevertheless appear, and all those phenomena which we have already observed will ensue. The minute germs which were protected in the interstices of the vegetable matter become developed into organisms resembling those from which they were derived. It seems almost impossible to destroy the germs without destroying the organic matter in which they were embedded and by which they may have been protected even from the destructive influence of boiling water.

Some experiments performed by Dr. Wyman seem to show that bacteria germs which would live in a solution which had been boiled might be destroyed by being boiled for six hours or longer.

There is reason for believing that many germs of low organisms exist which are far too minute and too transparent to be seen by the aid of the highest magnifying powers at our command, and that while in this condition rapid multiplica-

tion takes place. Gradually the minute particles acquire body sufficient to enable us to distinguish them from the clear medium by which they are surrounded. So that it seems to me the evidence against spontaneous generation increases in force as our means of investigation are improved. At the same time it must be admitted that this doctrine is still supported by some authorities of great repute.

At the conclusion of one of his interesting essays, my friend Dr. Child* puts a very pertinent question, and asks why creatures may not be formed piece by piece, "as M. Pouchet says, out of particles of dead matter, in the way which he and Schaafhausen and Mantegazza tell us that they have themselves witnessed?" To this I should venture to reply, that, as he is well aware, a host of facts have been brought forward against the theory, while no good reasons have been advanced in favour of supposing such a mode of origin of living forms to be *possible*. As regards *witnessing* such a formation of living beings out of dead matter all that can be said is, that other observers who have employed far higher powers than those referred to have never seen anything of the kind. My own conviction is, that if creatures are ever formed *piece by piece* out of *particles of dead matter*, the operation will never be witnessed by mortals, and I marvel that any one at all accustomed to careful microscopical observation could succeed in persuading himself that he had actually seen the phenomenon supposed to have occurred.† I consider the evidence that bacteria are

* "Essays on Physiological Subjects." Second edition. 1869. P. 111.

† Dr. Child comments very severely on the microscopic observations

not formed by the aggregation of particles of lifeless matter as conclusive aud as irrefragable as the evidence against any such mode of formation of mice, elephants, or men. Vague statements about the coalescence of molecules to form particles of protoplasmic matter, or physical basis of life, are not convincing. Every one naturally enquires what is the nature of the molecules alluded to, but he gets no answer. Of the molecules all, it may be admitted, are complex, but we are not told how the elements of which they consist are probably arranged, or what determines the new states of combination as the protoplasmic substance comes into being. To any one who has actually studied under the highest powers of the microscope (3,000 linear and upwards), the most minute living organisms, and has watched their movements and growth, the statements advanced in favour of spontaneous generation will appear hardly worthy of serious discussion, because he will feel quite convinced that for a long while before the living particle which he is able to see acquired the size and substance necessary to render it visible, it existed as a more minute and more transparent yet active and living particle, capable of growing and multiplying; and that the act of coming together of non-living molecules supposed, if it occurs at all, must take place in particles so very very far beyond the reach of observation and experiment, as to be quite undemonstrable, if not inconceivable. While, on the other hand, the further investigation is carried, the more reasons he gains

of M. Pasteur, but he says nothing of the powers employed, or the details of the microscopic investigations carried out by M. Pasteur's opponents.

for believing that the most minute individual particles he sees resulted from the division and subdivision of already existing particles. He sees the actual process of division taking place in hundreds of instances, and in every class of living things, from the very lowest up to man himself, and, in the absence of positive demonstration to the contrary, he cannot admit that any other mode of origin of living organisms of any kind whatever exists in nature.

It must then be regarded as a fact that living beings spring from pre-existing living beings, and that there is no such thing as spontaneous generation. Living forms continue to exist and to grow so long as the conditions of life remain favourable, but when these are changed, the organisms die.

Structure of a Spore of Mildew.—If one of the simple structures—the microscopic protoplasms such as are represented in the plate opposite p. 1, be examined (*a*), we shall find that it is not the same in every part. It consists externally of a delicate, transparent, glass-like texture, and within of a material having a faintly granular appearance. Suppose a little ordinary mildew dust, which is one of the lowest forms of existence possessing a very simple structure be examined. The little round bodies which compose it are larger than those above referred to, and will therefore suit the purpose of investigation better. Each of these has a tolerably thick well-defined outline, while the interior is perfectly transparent. When this transparent matter is examined under very high magnifying powers, numerous very minute particles like dots will be observed. Here then are two parts, the one situated externally, firm, glass like, and

arranged so as to form an investing membrane closed at all points, the other lying within, soft, and exhibiting no form or structure whatever. Now if these bodies be placed under favourable conditions certain changes will occur. Let them be put, for instance, upon the moist surface of a glass slide, and after a time let the slide be placed under the microscope. First of all the particles absorb moisture, and swell up, and the membrane becomes thinner in proportion to the whole mass, and the matter within increases in amount.

Next a new change is observed at one point in the membrane. A small orifice is seen, through which a little of the granular contents of the body, covered with a thin layer of the inner part of the membrane, makes its way, and thus a small nodule is formed which projects through the external membrane. By degrees this assumes a structure resembling that of the body from which it has proceeded; it increases in size; the membrane around it becomes thicker; its point of attachment becomes less and less, until at last it is completely separated, and becomes a free and independent particle, exactly resembling that from which it sprung, except that it is smaller, and capable of growing and giving rise to new individuals like itself, by a repetition of the process by which it was formed.

This is one way in which the particles may multiply, but there are others. In one of these, too, an orifice forms in the membrane of the particle of mildew, and a little of the soft transparent material escapes, but it does not separate as in the first case; it remains in connexion with the mass, and grows out into a narrow thread-like process. The mem-

brane on the external surface becomes thickened, and the whole increases in breadth. Within the sheath is found transparent matter, from which a number of little spherical bodies or very minute growing particles like those observed within the spherical spore may be obtained. It may be that as this process grows at one or more points a thinning occurs in its wall, and a portion of its contents coming into more immediate contact with the pabulum increases in amount, and thus gives rise to the production of another branch or process which grows exactly like the first.

Now, how does this simple organism nourish itself? The materials for its growth and nourishment are certain inanimate matters (solids and gases) existing dissolved in fluid in which the organism floats. These materials must pass into its structure and become part of it. That which is inanimate must become incorporated with and assume the properties of living matter. Now if such a living thing be placed under certain unfavourable conditions its vital properties will be destroyed. The transparent living matter in its interior will shrivel up and die, but this will be attended by no obvious alteration in the external membrane. The part which exhibits form (formed matter) remains; that which is without form (*living matter*) is destroyed.

In the growth of the structure, then, how is the new matter produced? Does it take place by deposition upon the external surface of the investing membrane, or is the new matter produced by the soft formless matter in the interior? To put the question still more simply, Is the capsule, the so-called cell wall, formed by deposition of

matter from the fluid surrounding it, or is it formed from within? and which is the oldest part of the capsule, its external or internal surface? If the new matter were deposited upon the external surface, we should expect to find that the membrane would become thicker and thicker as the growth of the organism advanced, while the central portion would remain unaltered. This, however, is not the case; on the contrary, we find that as growth proceeds, the wall in most cases becomes considerably thinned. It is clear, therefore, that the increase in size cannot be due to deposition from without. The matter deposited upon the *inner* surface of the capsule is always softer than its general substance, and the external surface of old capsules is cracked and ragged.

In many of the algæ this external surface serves as a nidus for the development and growth of smaller algæ—a fact which clearly shows it has ceased to be active, is undergoing disintegration, and becoming fitted for the pabulum of other things, and is no longer capable of resisting the action of external conditions. This is the oldest part of the capsule which is now undergoing decay, and the small algæ are living in part upon the products thus produced. The new material is added upon the inner surface of the capsule, layer after layer, and where there are several layers the innermost is the youngest and the outermost the oldest portion of the structure. If this be so, it follows that the inanimate material for the nourishment of these structures must pass through the outer membrane, and be taken up by the living matter within, which communicates to it the same properties and powers which this living matter itself

possesses, and which it has inherited from pre-existing particles. The nutrition of cells of epithelium of man is conducted upon the same plan. See p. 51. At present we cannot get further than this. I am ignorant of the nature of the changes which occur, but I think the facts as I have stated them are true.

Is a Tissue living because attached to a Living Organism. —Some appear to think that a change in position only will make all the difference as regards the proper application of the term *vital*, and seem to hold that a tissue should be called *alive* as long as it remains attached to a living body, *dead* when detached, irrespective of changes occurring in the tissue itself. But it is obvious that a leaf, or an elementary part, may be as devoid of life while it remains attached to the living trunk as after its connection with it has been completely severed. To say that a dead leaf exhibits life as long as it hangs on to the branch would be absurd, because differences of a much more important character proclaim whether the leaf be alive or dead, irrespective of its connection with the tree.

Not long ago, it was stated that a living thing might spring from a dying or dead one, as a fungus from a dead elm, by mere transference of force from the latter to the former,—that the departing life-force of one thing became transformed into the life of the new one, but those who advocated this view failed to prove that the fungus did not grow from the germ of a pre-existing fungus, and lived upon the disintegrating elm as other living things consume other kinds of pabulum.

Chemical and Mechanical Changes in Living Beings. —

Neither should changes which are admitted to be *mechanical* and *chemical*, when they occur in the laboratory, be called *vital*, merely because they take place in a living organism. It is the nature of the change alone which determines its vital or non-vital character. But the term *vital* is constantly applied to actions which, for the last fifty years, have been admitted to be mechanical and chemical, and the confusion with regard to the meaning of the word has been further increased by the assertion that mechanical and chemical actions are the *only* actions that are to be called *vital*. Some philosophers have indeed arrived at the conclusion that in truth there are *no vital as distinguished from physical and chemical actions*. Further, it has been held that as we can imitate osmose, oxidize certain substances and produce in the laboratory compounds like those formed in the body, we may prophesy that *all other actions* occurring in living beings *will eventually be imitated*. But it would be as reasonable to maintain that because we can now produce urea we shall by and by be able to form a hair or develop an eye out of the contents of a crucible, or that as we can build up by synthesis very complex organic compounds, ere long we shall be able to make a brain cell which will form ideas. Because we can make many products like those resulting from the disintegration of tissues, does it therefore follow that in the time to come we shall be able to develop an embryo by the admixture of two kinds of albuminous fluids prepared artificially?

As oxygen and hydrogen can be made to combine by the contact of platinum, therefore it is said certain

combinations of living particles are also examples of catalytic action. Because many actions have been attributed to vitality which are unquestionably physical and chemical, therefore all actions which are now regarded as vital will ultimately be proved to be physical. Those who argue in this way fail to perceive that they are dealing with two different classes or kinds of actions. The truth is physics and chemistry have never advanced one step in the directions indicated. Great things have been done, but in altogether different lines of enquiry. Strange as it may seem many undoubtedly high authorities have for years past failed to distinguish between the act of construction in the case of a machine or an organism, and the work performed by it after its construction is complete. They have failed to recognize any difference between formation and action, and have forgotten that before an organ can act or perform its function, it must be *formed*, and that its function and mode of action are in great measure determined by the changes which occurred during its formation.

The power or force which is concerned in the formation of an organ endowed with the most exquisite faculties is supposed to be of the same essential nature as that which causes certain kinds of matter to assume a definite crystalline form. The formation of organs and structures designed for the fulfilment of definite purposes which must have been foreseen, as it were, from the earliest period of development, is supposed to result from nothing more than the action and reaction of the properties and forces of the elements of matter concerned, and the external conditions to which it is exposed. But it must be borne in mind that

temporary structures are first produced which are useless in themselves and only serve as a provisional basis for the development of the masses of germinal matter from which permanent structure is to be evolved.

Actions in Living Beings.—A very little observation will convince us that in the body there are very different kinds of actions proceeding simultaneously. The formation and growth of muscular tissue would seem to be processes essentially distinct from its contraction, and yet both sets of phenomena have been attributed to the influence of the same forces. But building up and breaking down—solution and precipitation—development of structure and its removal —addition of matter to, and removal of matter from, a tissue—have been attributed to the operation of the ordinary forces. But not one of these phenomena as they occur in living beings can be explained by any known laws of physics, or imitated artificially.

"There are no truly vital actions," "there is no life,"—say some, and thus evade further discussion of this momentous question. But it has been shown that there is a marked distinction between the living matter and the formed matter (see p. 34), and that the phenomena going on in these two kinds of matter respectively are essentially different, and can be considered apart from one another. By ignoring altogether this and other important facts of observation, which have been demonstrated of late years, and by calling those who differ from them "vitalists;" by saying that facts opposed to their view are unimportant, and stigmatizing every argument against their doctrines as frivolous, making bold assertions, and under cover of jokes about

the fiction of vitality, popular teachers may partially succeed in forcing upon the people the acceptance of dogmas about force which are really untenable. The interest is excited by the very forcible and high-sounding terms employed, but the language is often remarkable for vagueness and laxity of expression, and conspicuous for its complete want of precision and clearness of meaning, and the use of terms that too often beg the question under consideration.

The matter in dispute has, at least as regards my own observations, been actually misrepresented; for—1. It has been said that the actions which I have termed *vital* are really physical and chemical. 2. The actions to which I have restricted the term *vital* (*see p.* 86), and which occur in the germinal matter only, have in many instances been completely ignored.

Force guided by Matter.— But although the new schools hold it absurd to suppose that any peculiar power acting from within or from without can influence the changes in matter, or direct its forces, they see no impropriety in attributing to matter itself, and to force, guiding and directing, and forming agencies. They transfer to the non-living those active, controlling, and directing powers which have been hitherto considered to be limited to the living world. It is the inorganic molecule, not *will*, or *mind*, or *power*, which governs, arranges, and guides.

Only recently, Professor Huxley has affirmed that a "particle of jelly" (protoplasm ?) guides forces.* But

* Mr. Huxley remarks, that to his mind it is a *fact* of the profoundest significance that "this particle of jelly (!) is capable of guiding physical forces in such a manner as to give rise to those exquisite and

the Professor has not explained what he means by guiding physical forces. He should have given us some idea of the property or force by virtue of which this jelly, this matter, is enabled to guide forces, and how the property was acquired. What are the laws which govern it, and how comes it that physical forces obey matter; what is the nature of the act of guiding spoken of? Does every kind of matter, under certain circumstances, guide forces, or only certain combinations of matter, or only special kinds of matter? Is it due to a mere command that is mysteriously obeyed, or to some repulsion or attraction, or if there be a subtle influence, what is the nature of this, and whence did it come? Here, as in many other cases, Mr. Huxley makes an assertion which he expects his pupils to receive without telling them the grounds he has for making it. No doubt Mr. Huxley feels quite satisfied that what he states is *true*. He speaks so authoritatively about *fact* and *law* ("fact I know, and law I know,") that one scarcely dares to venture to beg for an explanation of anything Mr. Huxley has affirmed. But students ask if Mr. Huxley's "facts" have been confirmed, and are anxious to learn something concerning the evidence upon which they are supposed to rest.

Why should the idea of the jelly guiding forces be a *fact* of profound significance, and the idea of "vitality" acting upon the particles of this jelly, and guiding them and their forces, be a *fiction*, frivolous, absurd, ridiculous, fanciful, &c.? Again; some think that physical forces

almost mathematically arranged structures," &c.—"Introduction to the Classification of Animals."

guide matter, but here we have the new doctrine taught that matter guides physical forces. But may it not be that neither matter nor force is capable of guiding or directing force or matter?

Mr. Huxley agrees with those who attribute to matter itself that which has been attributed by others to power acting upon the matter. One view is, that matter guides and rules itself of itself; another, that matter is guided and ruled by something acting upon it.

Concerning the dictum about jelly guiding physical forces, I shall venture to remark—1. That living matter is not jelly; 2. That neither jelly nor *matter* is capable of *guiding* or *directing* forces of any kind; and 3. That the capacity of jelly to guide forces, which Professor Huxley says is a *fact* of the profoundest significance to him, is not a *fact* at all, but merely an assertion.

Living matter is first called a name given to non-living matter; then it is asserted that this does so and so, which it has never been proved to do; this is next stated to be a fact of the profoundest significance; and by such devices the public is taught to believe in the creative and directing power of the non-living. Arguments of another kind have already led many to accept as an article of faith the dogma, that it is force alone which forms and builds, and designs and makes; and that the only source of the countless living things which people this earth is the sun,—"the God of this new world."

ACTIONS WHICH CHARACTERIZE EVERY KIND OF LIVING MATTER, BUT WHICH NEVER OCCUR IN ANY FORM OF NON-LIVING MATTER.

Let us now proceed to inquire whether there are any characters or phenomena which are common to all kinds of matter that lives, and manifested by this only. All living matter *grows*, and *moves*, and *forms*, of its own accord, while non-living matter cannot be made to do any of these things. Hence it is fair to say that growth, spontaneous movement, and formation are *vital phenomena*. We cannot at present conceive of life without a capacity for these phenomena. The actions may remain dormant for a time, but when circumstances are favourable, they manifest themselves very distinctly. Although in many cases *these vital phenomena* may be hidden and obscured by very evident physical and chemical changes, we shall invariably find evidence of them. By tracing the various actions in living beings towards their source, we shall always find that these *vital* actions underlie the rest, and contribute in a most important measure to the results we are able to observe, study, and investigate. And as neither growth, spontaneous movement, nor formation, have been imitated artificially, or known to occur in non-living matter, or proved to result from physical actions, I attribute these phenomena to *vitality*, or *vital power or force*, or to *life*, until a more satisfactory explanation shall be discovered.

*New views concerning the vital processes of Growth and Nutrition.**—The act of nutrition is peculiar to living beings and involves much more than the mere addition of new particles to a definite portion of matter, as some have held. *Growth* resulting from nutrition is so very different in its essential nature from every kind of increase resulting from deposition or aggregation, that it seems wrong to apply the word "growth" to the process of increase in the two cases. If the term is to be employed at all, with reference to living things, it should be restricted to them entirely, for a stone does not *grow* in the sense a living thing grows. Here, however, at the outset, I find myself distinctly at issue with one whose opinions on such questions are entitled to respect. At the same time I cannot help feeling that if the author in question had observed more for himself, and trusted less to the arbitrary dicta and inconclusive statements of others upon elementary questions of the highest importance, which, as he well knows, have been very imperfectly worked out, he would have been led to adopt conclusions at variance with the doctrines to which he has, I venture to think, prematurely committed himself. After affirming that the increase in size of the plant, *like the crystal*, is effected by continuously integrating surrounding like elements with itself, Mr. Herbert Spencer says† that the food of an animal is "a portion of the environing matter that contains some compound atoms like some of the compound atoms constituting its tissues." If such be so, the peculiar sub-

* The observations under this head formed the subject of a paper published in the *Trans. Mic. Soc.*, 1867.

† "The Principles of Biology," vol. i. p. 108.

stances of which white fibrous tissue, yellow elastic tissue, muscle, nerve, epithelium, &c., consist, ought to be present in the white and yolk of an egg before these have undergone conversion into the chick; but we know that not one of these things can be detected, and, in short, that development and growth are processes essentially and absolutely different from the mere deposition in a solid form of particles previously held in solution in a fluid. In *growth* the substances dissolved in the fluid pabulum are completely altered in composition and properties. Their elements are *re-arranged.* If the elements of the dissolved crystalline matter were torn asunder and then reunited in a different way, so as to produce a new substance when deposited in a solid form, crystallisation would in this one particular accord with growth; but there is not even this resemblance. A crystal, then, does not *grow.* The fungus-like (!) accumulation of carbon that takes place on the wick of an unsnuffed candle is not *growth.* The deposition of geological strata, the genesis of celestial bodies, are not examples of *growth.* I think that if Mr. Herbert Spencer would carefully study a growing microscopic fungus, he would modify his views concerning the nature of *growth*, and admit that there is an essential difference between this peculiar process and the above physical phenomena.

From what has been stated in many physiological works the student would be led to conclude that the *tissue* or *formed* matter of a living being to be nourished, selected from a mixed fluid, in consequence of some sort of affinity, certain constituents adapted for its nutrition, and that those substances passed at once from a state of solution to the

condition of tissue. But no instance is known in which any lifeless substance takes up another lifeless substance differing from it in composition, and converts this last into matter like itself, as occurs, for example, when a simple gelatin-yielding texture increases in amount, although surrounded by an *albuminous* material only in which no trace of gelatin-yielding substance can be detected.

In the hope of ascertaining the essential nature of the nutrient process, we must not limit ourselves to the consideration of the phenomena occurring in the fully-formed organisms of man and vertebrate animals, in which the nutrient blood plays so important a part; but we must extend our observation to plants and the lower organisms, some of which consist of extremely minute independent masses of matter. Many facts lead to the conclusion that *the nutritive process* is, at least in its essential nature, the same in all cases; and whatever meaning be assigned to the term, it ought to apply equally to the lowest simplest forms and to the highest and most complex.

A simple living organism takes up a quantity of nutrient matter and increases in weight. Having reached a certain size portions may be detached, and each of these, after absorbing nutrient matter, grows and gives rise to others. In this case the nutrient pabulum is converted into *living matter*, and as a result of nutrition there is an enormous gain in weight. But, on the other hand, living bodies may take up a considerable quantity of nutrient matter *without altering in weight*, and indeed some, in spite of being well supplied with nourishment, *actually lose weight*. The new matter taken up may exactly compensate for old

material which is removed, or more than compensate for this: or the process of removal may proceed faster than the process of nutrition. It is, therefore, obvious that nutrition cannot be held to mean the mere *addition of new matter to a living body*.

Suppose we now consider what actually occurs when simple living matter, like an amœba, or a white blood-corpuscle, or a pus-corpuscle, is nourished. Matter either in a state of solution or capable of being readily dissolved passes into the matter of which the living body is composed. Some of the constituents become part of the living body, while others are given off. The living body then increases in size. It is nourished and *grows*. In other instances, as in many of the lower vegetable organisms, and in the elementary parts or cells of the higher, a coloured material or matter having some peculiar properties is formed while the process of nutrition is proceeding. Now, this matter did not exist in the pabulum, nor was it to be detected in the living matter which absorbed the pabulum, but it has resulted from the *death of the living matter* under certain conditions. In this case, then, *the pabulum is first changed into living matter*, and the *living matter into the coloured or other formed material*. In some instances this formed material accumulates in the elementary part itself, as in the case of *starch* in vegetable cells and *fat* in animal cells, and there is a *gain in weight*. In other cases the formed material passes away from the germinal matter as fast as it is produced, dissolved in fluid or in a gaseous state, and *no alteration in weight occurs*, although a large quantity of nutrient matter is taken up.

Usually, of the formed material produced, part accumulates on the surface of the germinal matter and part escapes. Consider what occurs in the nutrition of ordinary yeast. A layer of cellulose matter which increases by the addition of new layers to its inner surface is formed externally. Within this is the transparent living or germinal matter. When such a particle is nourished, the pabulum passes through the cellulose wall into the germinal matter, and thus the substance increases; but at the same time some of the germinal matter becomes converted into new cellulose, which is added to that already existing, and alcohol, water, and carbonic acid, which escape. The germinal matter differs from the pabulum, and both differ in physical characters and chemical composition and properties from the cellulose envelope. *We cannot make the cellulose or the germinal matter from the pabulum, nor can the pabulum be obtained, as it was before, from either of the above substances.* How different are all these processes from the mere *addition* of matter previously held in solution, as occurs in the formation of a concretion, or a crystal, which increases by the superposition of layer upon layer!

Some writers, yielding to the suggestions of fancy and vague speculation, instead of resting upon the firm ground of observation and experiment, have endeavoured, without having at command facts to justify such a conclusion, to make people believe that there are forms very low in the scale of living beings which appropriate inorganic materials only, and which may, therefore, be very similar to the very first living things which appeared upon the earth, and are, in fact, according to this view, their direct descendants,

without divergence or modification; while, as we ascend in the scale, we are to recognize creatures more and more dependent for their existence upon beings below them which produce the food suitable for the subsistence of their snperiors. Just as the inorganic and lifeless gradually leads up to the organic, the living, and the mental, so such authorities would have us believe, are gradations of perfection, to be demonstrated as regards the nutritive process. From the stone that grows by the mere addition of matter upon its surface, there is a transition to the complex animal, the elements of whose food must be elaborated, perhaps, many times by lower and simpler creatures before the combinations suitable for the nutrition of their tissues are produced. But this is fiction, and it is fiction of a most unwarrantable kind, for the "facts" upon which all this rests are themselves fictions of the imagination. It is not true that some living things are nourished by inorganic matter alone, while others can only be nourished by matter which has been previously elaborated by living beings; nor is it true, in any way, that there is a gradation from the lifeless to the living. The lowest, simplest organisms require for their nutrition, besides inorganic material, a certain appreciable proportion of matter which has already lived; while, on the other hand, man himself appropriates water and mineral matters as well as elementary substances like oxygen, and these are as necessary for the nutrition of man's body as bread and meat. The chemist who regards oxygen merely as a substance which combines with certain constituents of the organism, as it combines with carbon during combustion, cannot be acquainted with many

physiological facts which render that view untenable in these days. It would almost seem as if by the "tendency" of scientific thought, a demand for certain theories of a certain tendency was from time to time excited. If that be so, no wonder there should be a good supply of new fancy facts and observations, for without some such support the tendency itself would soon lose its vitality.

I propose now to refer briefly to the vital process of *nutrition* as it occurs in man and the higher animals. It has been said that the life of the body is the blood, and it has been surmised that from this fluid the tissues derive not only the elements of their nutrition, but the *life* or the properties which we call by that name. But it is certain that the material nutrient pabulum adapted for the nutrition of the tissues, which the blood contains, is like all nutrient matter, *lifeless*, not *living*. The actual nutrition, the act of conversion of the pabulum that was in the blood into the tissue, is due to actions which occur outside the vessels, and is altogether independent of the passive nutrient fluid. As little supported by facts as the opinion above alluded to is the doctrine that arterial blood is very highly nutritious, although a student reading any of our text books would be led to believe that the highly nutritive properties of arterial blood had been proved beyond all question, and that every tissue to be nourished must have its nutritive artery. The very active nutrition going on in the lower animals and plants under conditions not favourable to free oxidation, and the fact that in man and the higher animals during the early periods of life when nutritive activity is most remarkable, the blood is not so highly

oxygenated as at a later time when the nutritive operations are comparatively slowly carried on, prove that this doctrine is erroneous.

Every one knows that food nourishes the body, and that the tissues are nourished by the blood, and it is generally believed that a high state of nutrition depends upon a liberal diet. At the same time, however, we know that the degree of nutrition exhibited by the body is not dependent merely upon the *quantity* or *quality* of the food introduced into the stomach, and absorbed and converted into blood, but upon a number of circumstances besides. In one individual much of the food taken may be excreted in an altered form soon after it has been introduced into the system, while in another a large proportion may become converted into tissue and little pass away. This difference is determined not by the pabulum, but by the living material which is destined to take this up, and which is concerned in the formation of tissue. Some men and some animals soon become fat upon a diet which to others would be extremely low; while certain individuals cannot be made fat, although supplied with abundance of the choicest and most fat-nourishing food. We must also bear in mind that *every* tissue in the body does not share equally in the increased nutrition, and although we often talk familiarly of the increased or diminished *nutrition of the body*, we refer for the most part to an increase or diminution of the adipose tissue, and, though to a much less extent, of the muscular tissue. At the same time we know that every tissue in the body is nourished from the earliest period of its existence; but that of all the tissues when the organism is fully deve-

loped the adipose and muscular are most influenced by altered diet. It may be said that the elementary parts of these tissues exhibit greater variation in activity than those of other textures. In some men and animals it would appear that the elementary parts of adipose tissue take up a larger share of nutrient matter in proportion than those of other tissues; while, on the other hand, the elementary parts of the glandular excretory organs are, in other individuals, the most active. The elements which in the first would slowly become an integral part of the body, as fat and other tissues, would in the last quickly escape as carbonic acid, water, and other substances, in the excretions. It is not possible to say why one set of tissues should be most active in one individual, and another set in another individual, any more than we can explain why a particular kind of food, which is most easily assimilated by one person or animal, should be useless or injurious to another.

As there are in the body many different tissues to be nourished, and many different substances in the blood which may nourish them, it is necessary to consider what particular constituents of the blood are principally concerned in the nutrition of the different textures. The opinion seems to have been very generally entertained that certain substances in the blood were destined for the nutrition of particular tissues, while other textures, it was supposed, selected from the fluid, constituents of a different character; for instance, it has been maintained that the red blood-corpuscles were specially concerned in the nutrition of the nervous and muscular tissues, while the white

blood-corpuscles nourished the fibrous textures—that fat selected fatty matter from the blood, muscle fibrinous material, and so on, but these notions are not supported by facts more recently demonstrated.

In a paper which I communicated to the Microscopical Society in 1864, I endeavoured to show that the blood, like the tissues, might be looked upon as composed of germinal or *living matter*, and *formed material.* The white blood-corpuscles and smaller corpuscles, probably of similar character, which last I showed were to be detected in the the blood, consist of germinal matter; while the red blood-corpuscles, the albumen, and some other constituents, are to be regarded as formed material, being composed of non-living matter, possessing, it may be, peculiar characters, properties, and chemical composition, but resulting from changes taking place in pre-existing germinal matter. The white blood-corpuscles, therefore, are themselves composed of living matter, which is nourished, and they cannot, as *white blood-corpuscles* contribute to the nutrition of any tissues whatever. Living matter never nourishes living matter, although, of course, the products resulting from the death of many forms of living matter do so in an eminent degree.

With regard to the red blood-corpuscles, it seems to me probable that they play a highly important part in equalising the temperature in all parts of the body, *taking away heat* from parts whose temperature is above the normal standard, and distributing heat to textures which are colder than they should be. At the same time it must be borne in mind that the red blood-corpuscles themselves are

gradually undergoing disintegration; and although it seems most probable that the constituents resulting from their decay are eliminated from the body in the form of urinary, biliary, and other excrementitious matters, it is most likely that some of the products take part in nutrition.

Upon the whole, however, it seems probable that the constituents which form the pabulum of the tissues are those which are contained in the serum of the blood; and it is impossible to conceive how minute quantities of pabulum prone to undergo rapid change could be more perfectly and equally distributed to the textures, without its composition being materially changed, than in the form of the very thin layers which each red blood-corpuscle carries upon its surface, and smears, as it were, upon the walls of the capillary vessel in intimate relation with the tissue. The arrangement is such as to reduce to a minimum the chances of alteration in the composition of the nutrient fluid as it traverses the vessels in different parts of the body.

From a careful consideration of the facts, I cannot help drawing the inference that the serum is the pabulum; that the red-blood corpuscles are concerned in its distribution, and in preventing changes in the composition of the great mass of the blood, as certain constituents are removed from it or poured into it; and that the white blood-corpuscles are masses of germinal matter concerned in the formation of the serum, as well as of the red blood-corpuscles. In support of this view, I would venture to direct attention to the following points:—

1st. That fibrous tissue, shell, cartilage, muscular and

nervous textures—the two last as perfect and, as far as we can make out, far more delicate, elaborate, and beautiful than any of the tissues of vertebrate animals—are formed, and with wonderful rapidity, in many of the lower creatures quite destitute of a nutrient fluid containing bodies corresponding to the red blood-corpuscles of the vertebrate blood; and that in all these cases the nutrient fluid is clear, transparent, colourless, and contains a substance closely allied to the albumen of serum, if not identical with it. Different plants and animals may produce from the *same pabulum*, and apparently under similar conditions, very different substances; and the different kinds of germinal matter in the body of one of the higher animals give rise to formed matters differing widely in structure, chemical composition, and properties.

2nd. That in man and the higher animals the development of the tissues corresponds to the period of life when the blood is not remarkable for the number or perfection of its red blood-corpuscles.

3rd. That certain morbid growths appear and increase rapidly in cases in which the blood has for some time contained a very small proportion of red blood-corpuscles.

It seems, therefore, probable that the substances taking part in the nutrition of all the different textures of the body are furnished by the albuminous matter of the serum, and that the production of muscle, nerve, fibrous tissue, &c., depends not so much upon the characters of the pabulum supplied as upon the *converting powers* of the germinal or living matter which appropriates this. The substances formed by germinal matter depend upon its *vital powers*

and the conditions under which these *cease to be manifested*, rather than upon the presence of particular substances in the papulum itself. Different kinds of germinal matter have power to rearrange the elements of the very same pabulum supplied to them, in different ways, so that one kind of germinal matter produces muscle, another nerve, another fibrous tissue, and so on; each of these tissues, and, of course, the pabulum itself, containing oxygen, hydrogen, nitrogen, carbon, and some other elements,—but differently combined and differently arranged.

Athough the opinion is still entertained by many anatomists that tissue—as, for example, the intercellular sub stance of cartilage—is deposited directly from the blood, no one has explained by what means the composition of the pabulum becomes so changed as it passes through the walls of the vessels to be distributed between the masses of germinal matter. On the other hand, the facts advanced by me several years ago in favour of the view that every kind of formed material passes through the state or stage of germinal matter have not been overthrown. The existence of germinal matter before the production of the formed material of cartilage and all other tissues; the continuity of the germinal matter with the formed material in tissues in process of development; the circumstance of no case being known in which formed material is produced without germinal matter; and the demonstration that fluids will pass through a comparatively thick layer of formed material, and reach the germinal matter in the course of a few seconds, have forced upon me the conviction that pabulum invariably passes to the germinal matter, and some

of its constituents, undergo conversion into this active living substance, and acquire its properties and powers,—portions of the germinal matter from time to time losing their original vital properties, and undergoing conversion into lifeless formed material.

So far, then, it would seem that in the process of nutrition pabulum passes into living germinal matter, and is converted into this substance. The formed material or tissue which, in many cases, constitutes the chief increase in weight and bulk, has all passed through the state of germinal matter. The formation of this germinal matter from the pabulum is therefore the important part of the process, but it is one most difficult to investigate, if indeed it be not altogether beyond the province of investigation.

It is most interesting to inquire by what means the soluble pabulum is caused to pass into the germinal matter. No form of attraction or affinity that we are acquainted with will account for the passage of pabulum towards and into the germinal matter. The question is one upon which I have ventured to speculate. The tendency which every mass of germinal matter exhibits to divide into smaller portions, each part appearing to move away from other portions, suggests the idea of there being some centrifugal force in operation. This moving away of particles from a centre will necessarily create a tendency of the fluid around to move towards the centre; I think, therefore, that the nutrient pabulum is, as it were, drawn in by centripetal currents, excited by the centrifugal movements of the particles of the living germinal matter. How is it that vitality gives to matter the power of moving away from centres I cannot

even attempt to explain. That this is so, is rendered probable by many general facts, open to the observation of all, as well as by the wonderful phenomena seen with the aid of the highest powers of our microscopes.

The point in which every nutritive operation differs essentially from every other known change is this: the composition and properties of the nutrient matter are completely altered, its elements are entirely rearranged, so that compounds which may be detected in the nutrient matter are no longer present when this has been taken up by the matter to be nourished. The only matter capable of effecting such changes as these is living matter, and it is very remarkable that when this matter ceases to live, we do not detect amongst the compounds formed at its death substances previously present in the pabulum, but new bodies altogether, and these often vary according to the circumstances under which the matter dies.

Desiring as I do to yield all that can be yielded to those who maintain that there is no vital power distinct from ordinary force, I might say that a particle of soft transparent matter, called by some living, which came from a pre-existing particle, effected, *silently and in a moment*, without apparatus, with little loss of material, at a temperature of 60° or lower, changes in matter, some of which can be imitated in the laboratory in the course of days or weeks by the aid of a highly skilled chemist, furnished with complex apparatus and the means of producing a very high temperature and intense chemical action, and with an enormous waste of material. It is, therefore, quite obvious that an independent, thoughtful person, must, for the present, hold that the

operations by which changes are effected in substances by living matter, are in their nature essentially different from those which man is obliged to employ to bring about changes of a similar kind out of the body; and until we are taught what the agent or operator in the living matter really is, it is surely permissible to call it *vital power*. Its actions cannot be denied and ought not to be ignored.

It seems to me childish, rather than philosophical, on the part of any one to reassert in these days that nutrition is merely a chemical process, unless he can imitate by chemical means the essential phenomena which take place when any living thing is nourished. The passage of a fluid through a tissue by which its structure is preserved is not *nutrition*, or the introduction of preservative fluids into dead tissues would be a nutritive operation. A fluid may hold in solution certain substances which are separated from it as it traverses the tissue, thus adding weight and altering the properties of the tissue, as occurs when calcareous and other slightly soluble substances are deposited in the soft matrix of bone, teeth, shell, and other textures. This is a process which can be made to take place in lifeless matter, and has been adduced in support of the doctrine that the tissues of plants and animals are formed by physical and chemical agencies only; but it is not *nutrition*. Those who advance such arguments confuse the process of deposition of insoluble salts in a material previously formed, with the actual *formation* of the material itself out of substances of a totally different composition.

Nutrition, then, involves the conversion of lifeless pabulum into living germinal matter, and comprises these steps.

1. The contact of the soluble pabulum with the germinal matter.

2. The separation of the elements of the nutrient substance from their state of combination as pabulum.

3. The rearrangement of the elements, and the conversion of some of these into new germinal matter.

Nutrition is impossible unless living germinal matter be present, and in every case in which it is known to occur new germinal matter is produced. Nutrition is a *vital* process, its occurrence is positive evidence of *vitality*, and nothing like it has ever yet been effected by human ingenuity.

Of Vitality.

How are we to explain the wonderful changes which take place in the germinal or living matter, and how are we to account for the capacity which this exhibits of passing through orderly series of changes, the last of which seems to have been provided for, and, as it were, anticipated from the very first?

I regard "*vitality*" as a power of a peculiar kind, exhibiting no analogy whatever to any known forces. It cannot be a *property* of matter, because it is in all respects essentially different in its actions from all acknowledged properties of matter. The vital property belongs to a different category altogether.

That the properties of elements which disappear, or are changed when compounds are formed, are really retained, can be proved, because when each element is again isolated it manifests its elemental properties; but the *vital*

properties are lost whenever living matter dies, and are never regained by those same particles. The vital actions of the highest and lowest known forms of living matter appear to be of the same essential nature, although the results of vital actions upon the form, properties, and composition of the material produced are very different in different organisms. But between the vital actions of the simplest and most degraded forms of living matter, and any actions that are known to occur under the most complex circumstances, in non-living matter, there appears to be no analogy whatever. Instead of attributing the phenomena peculiar to living beings to any force or power of a peculiar or special kind, it is considered more in accordance with the "tendencies" of scientific investigation in these days, and much more philosophical to assert that the phenomena which I have called *vital* are the consequences of antecedent physical phenomena.

When one portion of a mass of living matter is seen to move in advance of other portions it may be said that the movement is due to some phenomenal alteration which occurred just before. But what evidence have we that this change, which cannot be rendered evident to our senses, was really *phenomenal*? This movement is one of the essential attributes of living matter. We cannot conceive of living matter without the capacity for such movement. The growth of the forest could no more be accomplished without this wonderful power of movement which overcomes the attraction of gravitation, than the changes in form of the simplest living particles, or the active movement of the vibrio or the vibration of a cilium. The visible changes

which occur in the form of a mass of germinal or living matter undoubtedly succeed and are a consequence of *antecedent* changes, but what do we know about these antecedent changes? All we have learnt positively is that the matter moves in a manner peculiar to matter of this kind. Shall we account for the movement by saying—that it is a consequence of antecedent phenomena—or that it is due to an inherent tendency to move—or to a property which it has derived from matter like it from which it came—or to some mysterious agency acting from without or from within, or to the action and reaction of forces acting in both directions? It is not possible to *prove* why the matter moves because we have no means of investigating its state just prior to the occurrence of the actual movement, but the universality of this movement in the living world convinces us that it is of the highest importance and very intimately related to life itself. This movement has been shown to be peculiar, and so far has not been excited in any form of non-living matter. Is it not, therefore, reasonable to suppose that the condition which immediately precedes the occurrence of actual movement is also peculiar to living matter? But is it a *phenomenal* change? Some action, state, or condition, must undoubtedly take place in the matter just prior to movement, differing from the condition or state which obtains in the living matter when no movement is about to occur, but we cannot demonstrate any difference whatever; neither have we yet been able to discover any means by which the state of change just preceding active movement can be distinguished from the state of ordinary and comparative rest. We do not in fact know when a movement is about to

occur, we only know the fact of its occurrence. If the state just preceding movement is to be attributed to antecedent phenomena, the state of rest might with equal propriety be attributed to the very same antecedent phenomena. It is doubtful if the word phenomenon is at all applicable to the supposed change in the relations of the particles of living matter which results in actual movement. Is it correct to speak of a condition or state which cannot be rendered evident to the senses, as a phenomenon? A certain change common to every kind of living matter occurs just prior to the movement of its particles, which universally distinguishes this from every other known state of matter. As the movement is peculiar, its cause must be peculiar, and it seems more reasonable to attribute this to some peculiar power manifested by living matter only, than to an antecedent phenomenon which is different in its essential nature from every other action or change to which the term phenomenon has been applied. In truth, when we enter upon the consideration of the cause of the changes in living matter, we soon get beyond the limits of observation and experiment. It may of course be said that such discussions are therefore futile and out of the province of science. But if this view be accepted we must cease to enquire almost as soon as we have commenced to investigate. In that case the consideration of the growth, formation and action of the simplest being, and of every elementary unit entering into the formation of the tissues of every living creature, must be as a sealed book. And it would be absurd to attempt to describe the processes of growth, formation and secretion, as they occur in living

beings. The question not only lies at the very root of physiology, but forces itself upon our consideration at every step. It must, therefore, be discussed, and provisional hypotheses may be advanced if only to mark the paths already traversed in the course of our difficult and never-ending exploration.

That the physical school should try to stop all enquiry at this very point is exactly what might be expected, for the subject is obviously out of the path of physical enquiry, but it by no means, therefore, follows that nothing is to be learnt concerning it. No wonder that those who would have us believe that the highest aspirations of the soul are but manifestations of so many units of force, desire to chain the mind so tightly to the material that it shall no longer exercise one of its remarkable endowments—that of stretching towards regions into which the senses cannot penetrate. Is the mind to follow the senses, instead of leading, controlling, and directing them? Are the senses to govern the intellect and to dictate to it the conditions under which it may work? But even the disciples of the physical school cannot altogether refrain from advancing vain speculations and fanciful hypotheses. Is it then the attempt to speculate in one particular direction that gives such offence in these days, and which some try to put down, with firmness and force? The new school professes to consider all enquiries worthless which are not conducted by experiment and observation, and yet how many obscure and doubtful facts of observation and experiment are advanced and used as scientific certainties, when the magic light of physical theory has been projected upon

them? It is indeed very desirable to bring us face to face with "facts," but it is astonishing how many grand facts of the profoundest significance are slowly resolved into harmless fictions of the imagination condensed and duly concentrated into very strong language to suit the dictates of a party determined to make people think in one way only, or to prevent them from thinking at all. But the authoritative language of opponents need not deter us from entering upon the discussion of a matter which is of more than ordinary interest to all, and I shall venture to draw certain conclusions concerning the probable nature of life; although I can only receive indirect assistance from observation and experiment.

There is in living matter nothing which can be called a mechanism, nothing in which structure can be discerned. A little transparent colourless material is the seat of these marvellous powers or properties by which the form, structure, and function of the tissues and organs of all living things are determined. But this transparent material possesses a remarkable power of movement, which has been already referred to (*see p.* 39). It may thus transport itself long distances, and extend itself so as to get through pores, holes, and canals too minute to be seen even with the aid of very high powers. There are creatures of exquisite tenuity which are capable of climbing through fluids and probably through the air itself—creatures which climb without muscles, nerves or limbs—creatures with no mechanism, having no structure, capable when suspended in the medium in which they live, of extending any one part of the pulpy matter of which they

consist beyond another part, and of causing the rest to follow; as if each part *willed* to move and did so, or moved in immediate response to mandates operating upon it from a distance, governed by some undiscovered, and at present unimagined laws,—creatures which multiply by separating into two or more parts without loss of substance, or capacity, or power. It would seem that each part possessed equal powers with the whole, for the smallest particle detached may soon grow into a body like the original mass in every respect; and the process may be repeated infinitely without any loss or diminution in capacity or power. It may be asked if there is anything approaching this occurring within the range of physics or chemistry.

Of a Living Spherule.—Let us imagine we could look into the ultimate particles of the living, active, moving matter, and consider what we should probably discern. I think we should see spherules of extreme minuteness, each composed of still smaller spherules, and these of spherules infinitely minute. Such spherules have upon their surface a small quantity of matter differing in properties from that in the interior, but so soft and diffluent that the particles may come into very close proximity. In each little spherule the matter is in active movement, and new minute spherules are being formed in its central part, and these are making their way outwards so as to give place for the formation of new ones, which are continually appearing in the centre of every one of the living particles. The rate of growth of the entire mass varies with the rate at which the new particles are evolved in the centre.

Each spherical particle is free to move in fluid, and the intervals between the particles are occupied by fluid. This fluid contains, in solution,—

1. Matter about to become living;

2. Substances which exert a chemical action, but do not necessarily form a constituent part of the living mass, together with particles which are rejected, and not capable of being animated; and

3. Substances resulting from the changes ensuing in particles which have arrived at the end of their period of existence, and the compounds formed by the action of oxygen upon these.

There can be no doubt that the smallest particle of living matter is complex. It is impossible to conceive the existence of a living particle of any simple substance like iron, oxygen, nitrogen, &c.; for *living* involves changes in which several different elements take part. It seems to me, therefore, that the term *living atom* cannot with propriety be employed, seeing that *living matter* is of complex composition, while the idea of an *atom* seems to nvolve simplicity of constitution, if not indivisibility. The whole question of the arrangement and form of the atoms in living matter can at present only be discussed theoretically; and I would now merely remark with reference to this subject, that although all living particles are of complex composition, many different elements may exist in very different proportions in living matter; and that there is reason to believe that the smallest particles of *every kind* of living matter are spherical. It is not possible to see, with the highest powers now made, particles which would in all

probability be demonstrable by more perfect glasses. But there is reason to think that in any case we must fail to see the actual particles, which are the seat of change, in consequence of their extreme tenuity and transparency. There must, indeed, be centres more central than the most remote spots which can be rendered evident to the senses, and it is not possible to conceive an actual centre. The most minute molecule must be compound to its very centre, and yet the resolution of complex matter into their elements must take place, and the re-arrangement of these in a new manner must occur in the central part of every molecule of which every mass of living matters consists. The further consideration of this question is of the deepest interest; but the inquiry assumes a too purely speculative character for me to pursue it here, as I am anxious not to diverge very far from the consideration of matters which may be investigated by observation and experiment. It seems, however, to me probable that the wonderful changes occurring when inanimate matter becomes living, which occur in living beings alone, take place in the central part of the spherical particles of germinal matter only. Discussions as to the nature of the vital forces must, I think, therefore be confined to the consideration of the changes which take place in those minute living spherules of which there is reason to believe we can only see some which are comparatively of large size, and probably many series removed from their ultimate spherical components.

Centrifugal Movement of Living Particles.—Movement takes place in the most minute living particles in a direction from centre to circumference, while the inanimate matter

which is about to become living passes in the opposite direction (*see p.* 47); or, in other words, the inanimate matter passes into the centre of a particle which already lives, becomes *living*, and then moves outwards. The flow of the inanimate matter is *centripetal*, and the movement of the living matter is *centrifugal*. But both sets of movements are to be accounted for by the centrifugal tendency of the living matter; for it is obvious that as it thus tends to move from a centre, a flow in the opposite direction must be induced. Such tendency to move from a centre, it would seem, must be due to a force very different from that which controls the movements of inanimate matter. Moreover, while cosmical force influences masses of the largest magnitude and of infinite minuteness, through varying distance, the vital forces can only exert their sway when the distance is infinitely short; and it would seem that this influence can only affect matter which has arrived at the very centre of the living particle.

New Centres not formed by Aggregation.—It cannot be supposed that the new centres of living matter are in any way formed by the aggregation of particles derived from distant parts; for, if this were so, these living particles must have traversed formed material, and passed to the very centre of the living germinal matter. But we have ample evidence to prove that the movement of living particles is in one direction only, *from* and not *towards* centres. Moreover, there is reason to think that the only matter passing towards centres is *dissolved non-living pabulum*, and if living particles were suspended in this, they would be filtered off by the formed material, and would never

reach the living matter. The arrangement is such as to permit fluid only to go to the living matter, and check the passage of all insoluble particles of whatever kind. While, if we admitted as possible the aggregation of millions of particles having different properties and powers, we should still be quite unable to explain how it was that they did not interfere with one another's interests; why, for instance, the most vigorous did not grow at the expense of their weaker brethren, starving them by appropriating their pabulum, destroying them utterly, and occupying the space which they had not the strength to retain.

Alteration in Vital Power.—It is remarkable that the results of the act of living in different masses of germinal matter having the same origin should be very different. And in the development of new centres one within the other, the masses last produced seem to have acquired powers which their progenitors did not possess. In the formation of the ovum itself the production of centre within centre proceeds for a long time before the actual mass from which the new being is to be evolved is produced. On the other hand, thousands of masses of germinal matter are formed during the early periods of development, which apparently only serve the purpose of giving origin within themselves to others from which those which are to take part in the formation of tissues are at length developed. Thus, many successive series of masses of germinal matter are formed, and are succeeded by new ones before those by which the tissue or organ is to be formed are produced. And these result from the development of new centres or nuclei within already existing

living matter. Each successive series of nuclei seems to acquire new power, although there are no characters by which it could be distinguished from any pre-existing or succeeding series. That there is a difference is, however, proved by the difference in the results of living. Moreover, at the same time that the new centre acquires new powers, it retains by inheritance some of those possessed by the germinal matter that preceded it, and hands these down to the new centres it originates. It would, therefore, appear more in accordance with the facts to conclude that the powers exhibited by the last of a series of masses of germinal matter were somehow retained in relation with the matter of every one of its predecessors, and thus handed down from generation to generation, than to assume that the new powers were acquired in consequence of the different series being successively exposed to different external conditions. But this last view is really untenable, because we have abundant evidence of the transmission of peculiar properties and powers, through a vast number of successive units during a considerable period of time, and though sometimes dormant for a while, they are yet at last manifested so distinctly that no doubt could be entertained as to their actual transmission from particle to particle.

Increased Action.—Increase in formative and constructive power seems to be associated with the most limited change in germinal matter, while rapid change—increased vital action—seems to be invariably connected with decadence in power. How can such phenomena be in any way due to the influence of the ordinary forces associated with lifeless matter? No form or mode of force yet discovered

has been known to act in any way at all analogous to this. The results must, therefore, be attributed to some peculiar power capable of controlling and directing both matter and force.

It has been suggested that the different substances and different structures produced by germinal matter at different periods of development may depend upon the different surrounding conditions present when the changes occur. This, however, is no explanation at all, for the surrounding conditions to which a mass of living matter in a growing organism is exposed, as well as the circumstances concerned in the production of these, are complex. They are not simple external conditions, but are in part the result of external circumstances, and in part of a previous state of things in the establishment of which pre-existing vital powers, associated with germinal matter, played no unimportant part. It has been shown that the production of formed matter is due to the death of living matter under certain conditions, which is itself a highly complex phenomenon, and cannot be explained without supposing—1. Certain *internal* forces capable of causing the elements of the matter to arrange themselves in a certain definite manner totally different from that in which the ordinary forces of matter would cause these elements to be arranged; and 2. Certain *influences operating from without* (*i.e.*, surrounding external conditions) tending to prevent the supposed internal forces from exerting their sway. The composition, structure and properties of the matter produced, must, it seems to me, be referred to the influence of these different antagonistic forces acting upon matter in opposite directions.

All this, which takes place in all living particles, seems very different from anything going on in non-living matter.

Hypothesis of Vital Force.—It seems to me that the facts cannot be accounted for except on the hypothesis of the existence of some force or power which influences, in a manner we do not yet understand, the ultimate elements, or the compound molecules, and causes them to take up particular relations to one another, so that when they combine, compounds possessing special characters shall be formed. For, surely it cannot be maintained that the atoms arrange themselves, and devise what positions each is to take up,—and it would be yet more extravagant to attribute to ordinary force or energy, atomic rule and directive agency. We might as well try to make ourselves believe that the laboratory fire made and lighted itself, that the chemical compounds put themselves into the crucible, and the solutions betook themselves to the beakers in the proper order, and in the exact proportions required to form certain definite compounds. But while all will agree that it is absurd to ignore the chemist in the laboratory, many insist upon ignoring the presence of anything representing the chemist in the living matter which they call the "cell-laboratory." In the one case the chemist works and guides, but in the other it is maintained, the lifeless molecules of matter are themselves the active agents in developing vital phenomena.

Some have taught that mind transcends life, and life transcends chemistry, just as chemical affinity transcends mechanics. But no one has proved, and no one can prove, that mind and life are in any way related to chemistry and

mechanics. If the step from mechanics to chemistry is known, has been proved, and is admitted, that from chemistry to life is assumed, and assumed without the slightest reason. If it had been shown that there was some sort of relation between A and B, and another sort of relation between C D, would any one venture to argue that, therefore, B and C must be related? Neither can it be said that life works *with* physical and chemical forces, for there is no evidence that this is so. On the other hand it is quite certain that life overcomes, in some very remarkable and unknown manner, the influence of physical forces and chemical affinities. Does the tree grow away from the earth or its roots into it, in obedience to the laws of gravitation? Are certain things taken up from the soil and others rejected, or do the leaf cells tear away from carbonic acid its carbon, and drive off its oxygen by reason of chemical affinity? Of course, it will be said that capillary attraction, osmose and other forces, contribute in a highly complex manner to bring about the results; but every one at all acquainted with the subject knows, that the facts have not been, and cannot be explained. Such questions are usually evaded by those who profess to explain them. I ask for one single instance in which the phenomena actually occurring in any living thing, or in a particle of living matter, can be adequately explained by physics and chemistry. The only answer I get is, that if the phenomena cannot be explained now, it is certain they will be at no very distant period. One must, however, acquire prodigious physical faith before one can hope to believe that prophetic physics and chemistry are as worthy of acceptance

and as convincing to the reason as facts of observation and experiment.

If the explanation of the facts by calling in the aid of some agency, force, or power totally distinct from ordinary force is unsatisfactory, is it not more unsatisfactory, nay, is it not even false, to attribute them to the action of the ordinary cosmical forces, concerning which much is known, but which have never been proved to be capable of effecting any changes at all like those which occur in every kind of living matter?

And it would surely be more in accordance with the true spirit of science, at least while our knowledge remains very imperfect, to study still more carefully the phenomena of the simplest known forms of living matter than to affirm boastingly, that not only these phenomena but those manifested by the highest form living matter is known to take, undoubtedly, result from the influence of mere force which never made a brick or formed a wheel, but yet is held capable of constructing those most wonderful and most beautiful mechanisms which could never have been conceived by the most vivid imagination, but which are being revealed to us in new multitudes day by day in glorious perfection. Surely, these no more result from the fortuitous or force-impelled aggregation of atoms than pictures, statues, mills, or ships do.

If, then, we take a general survey of the phenomena peculiar to living things, I think we shall find ourselves compelled by the facts to accept some such inferences as the following:—

In all living beings there exists matter in a peculiar state which we call *living*. This living matter manifests phenomena which are different from any phenomena proved to be due to the operation of any known laws. It moves in a manner which cannot be explained by physics. Changes are effected in its composition which cannot be accounted for, and various substances are formed by it which may exhibit structure, properties, and a capacity for acting in a manner which is peculiar to living beings, and cannot be imitated artificially or satisfactorily explained. It takes up non-living matter in solution, and communicates its wonderful properties to it. Having increased to a certain size, the mass of living matter divides into smaller portions, every one of which possesses the same properties as the the parent mass, and in equal degree.

Scientific investigators have hitherto failed to discover any laws by which these facts may be accounted for. But rather than ignore or misrepresent them, or affirm anything concerning them which we cannot prove, as some have done, it seems to me preferable to resort provisionally to hypothesis. In order to account for the facts, I conceive that some directing agency of a kind peculiar to the living world exists in association with every particle of living matter, which, in some hitherto unexplained manner, affects temporarily its elements, and determines the precise changes which are to take place when the living matter again comes under the influence of certain external conditions.

In higher animals, besides giving rise to the phenomena above referred to every instant during life in every part of the organism, this supposed agency or power, acting under

certain circumstances at an early period of development, so disposes the material which it governs, that mechanisms result of most wonderful structure, at any rate admirably adapted, if they have been actually designed, for the fulfilment of definite purposes. These mechanisms were anticipated, as it were, from the earliest period, and their formation provided for by the preparatory changes through which the structures had to pass before perfect development could be attained. Can these phenomena be accounted for except through the influence of some wonderful power or agency such as we are now contemplating?

Of all organic mechanism, the most perfect, the most exalted, and as regards mere structure the most elaborate, is the nervous. Widely diffused, intimately concerned in the actions going on in various tissues, and co-extensive with most of these, it sends filaments to the very confines of the organism. Through this mechanism alone, the very last to be perfected, external changes affect the peculiar form of living matter with which it is in the closest relation, and are thus rendered evident to the living being. The changes occurring in the central living matter of the nervous apparatus may give rise to secondary, combined, and complex actions, through which various ends may be accomplished. These internal impulses are themselves the movements of the particles of the living matter induced by the supposed vital power or agency acting upon them.

In animals yet higher in the scale of creation, the nervous mechanism through which alone the vital power influences other tissues, so as to give rise to associated and combined acts, is still more perfect and elaborate; but it is

formed according to and acts upon the same principles. Actions most complex are carried out through the influence of what is ordinarily termed *will.* This is essentially related to life itself, and probably is the *vital force or power* of certain kinds of living matter. But it must not be supposed that vital phenomena are due to will alone, for in all cases these occur long before there are any manifestations of will, as the term is ordinarily understood,—indeed, before the tissues through which alone *will* operates have been developed. At all periods of life there are tissues which live and grow independently of the influence of *will.* Neither can *instinct* nor *mind* be regarded as *life*, although I think these, as well as *will*, are forms of *vital power.*

In man there seems to be seated in and limited to a special part of his nervous mechanism, a still higher and more wonderful power, influencing a very special and easily destructible living matter. By virtue of this power man alone, of all created beings, is impelled to seek for the causes of the phenomena he observes, and is enabled to devise new arrangements of material substances for his own definite purposes, and in a manner in which these substances were never arranged before, and in which it is not conceivable they could be arranged without man's design and agency. The power supposed, totally distinct from any forces or properties of which we are cognizant, and not in any way correlated with any known forms or modes of force of which we have any experience,—exerts its sway upon any definite portion of matter, during varying but usually only very brief periods of time, often momentarily, and is then transferred to, or passes on, and influences new particles.

From these the powers are transmitted to others, and so on. The amount of matter influenced at any one moment being greater in some situations than in others, and varying according to a number of circumstances. In relation with the delicate living matter, seated near the surface of the grey matter of the convolutions of man's brain, which is alone concerned in mental action, I conceive that vital power attains its most exalted form. It seems to be temporarily chained, as it were, to this matter, which it acts upon, and through which alone it can make itself evident; but seeing that all forms of vital power are transferable, surely there is nothing contrary to reason in supposing that it may be freed from the material, and yet be.

OF MIND.

Of Nerve Action in General.

IT has been very generally concluded that the peripheral excitation of a nerve is due to some change taking place in the *nerve fibre* itself; and it must be admitted that some of the most recent anatomical observations in Germany favour this view, inasmuch as fine terminal filaments of nerve fibre *destitute of germinal matter* said to ramify amongst the anatomical elements of certain are tissues. And these fibres are represented as terminating in *free ends*, which may reach the surface of the cuticle for example, and even come into actual contact with anything which touches it. But those who describe and figure such fibres amongst the epithelial cells of an epidermic tissue, do not tell us how they were formed, and how they came into the positions in which observers profess to demonstrate them. Many of the appearances represented in recent drawings of the supposed nerve terminations, have long been familiar to me, but I cannot accept the interpretation which has been given. It is curious that lines between certain epithelial cells, which by some have been looked upon as *nerves*, have been regarded by other observers as lymphatics, the tubes of which it has been said have been actually filled with colouring matter. Careful observation,

under most favourable circumstances, has forced me to dissent entirely from both views. In every case in which I have been able to demonstrate the finest nerve fibres I have succeeded in proving the existence of germinal matter in connection with them.

There is, however, no doubt that nerve action is influenced by pressure upon the fibre of a nerve without any change in germinal matter. In many nerves of the higher animals a considerable length of axis cylinder intervenes between the nerve centre and the peripheral distribution of the nerve fibres, which is destitute of germinal matter, but which, nevertheless, receives and transmits nervous impressions made upon it in this part of its course. So that, although absence of germinal matter from a considerable extent of peripheral nerve fibre does not justify the conclusion that the nerve fibre in question is not an active fibre, the mere statement that very fine fibres have been seen amongst epithelial or other cells, and constitute the essential part of the peripheral nerve apparatus, must be received with the greatest caution. Until these supposed nerve fibres have been actually followed into undoubted nerve trunks, and the manner in which they were formed has been clearly pointed out, we cannot be expected to assent to the conclusion that the appearances described are really due to nerves at all. In all tissues of vertebrata in which I have studied the very fine peripheral nerve fibres, I have succeeded in tracing them into undoubted nerve trunks, and I have always detected numerous masses of germinal matter in connection with these fibres, as will be found figured in my drawings. Moreover, the germinal matter is more abun-

dant in the terminal portions of the peripheral nerve organs that I have studied than in any other situations. I should, therefore, doubt if terminal fibres which were destitute of germinal matter were nerve fibres at all.

From a consideration of the facts we are led to conclude that the nerve fibre in all cases transmits the nerve current as a conductor, and that pressure, &c., upon any part of its course will affect the rate of transmission of the current and the conducting property of the fibre, but that the current originates in germinal matter.

That the masses of germinal matter, which I have shown to be numerous in the fine nerve fibres of nerve organs, besides taking part in the formation of the fibres, are concerned in nervous action, appears therefore to me probable from the following facts :—

1. They are very numerous in the peripheral ramifications of all nerves.

2. All special peripheral nerve organs, as the retina, the expansions of the olfactory and auditory nerves, the papillæ of touch and taste, as well as the peripheral nervous expansions beneath sensitive mucous membranes, the skin, &c., are remarkable for the great number, as well as for the large size, of the masses of germinal matter.

3. The proportion of germinal matter is always very great in nerve centres, which there is abundant reason for regarding as the principal seats of development of the nerve force.

4. That where, as in the sensitive papilla upon the toe of the frog, the nerve organ is more acutely sensitive (or more active in any other way) at one part of the year than

at another, its increased activity is associated with a great increase in the amount of the germinal matter.

5. The principal change which takes place in a texture which in health appears to be but slightly sensitive, and becomes eminently so when inflamed, as the peritoneum, is a very great increase in the germinal matter which it contains and this often proceeds to such an extent that the ramifications of the nerves appear as lines of oval masses of germinal matter, so that when a tissue which in the healthy state gives no evidence of sensation becomes acutely painful when inflamed, the feeling of pain must be due in some way to an increase of the germinal matter of the nerves as well as that of other tissues.

Of the Nerve Current.—The nerve current itself probably results in a great measure from changes occurring in the germinal matter of the nerve centres, or more probably in the chemical compounds immediately formed by it; and the masses of germinal matter in the peripheral nerve organs most likely give origin to feeble currents in much the same way. In disease the intensity of the currents formed at the periphery of the nerves is probably increased.

With regard to the nature of the nerve current little positive is known, the general opinion of physiologists being that it is some mode of force correlated with heat, electricity, &c., but not exactly identical with any form or mode of energy known. The arguments upon which this opinion is based appear to me very inconclusive. Is it reasonable to assume new modes or forms of force? Surely the evidence is strongly in favour of the view that the nerve current *is* electricity, and I think that most, if not all,

the phenomena familiar to us may be explained upon this view. Some physiologists have sought to account for the wonderful phenomena of the nervous system by supposing that some force or power of a peculiar and exceptional kind is at work, and it seems scarcely to have occurred to them, if ordinary force, as electricity, be made to travel in different directions, and the currents combined in various ways and made to traverse series of conducting cords very specially arranged, according to design, the phenomena may be accounted for without resorting to the hypothesis of the existence of a peculiar mode or form of force not yet discovered.* And it is more probable that the various effects are determined by alterations in the intensity of the current, and in the conducting properties of the fibres than by *different kinds of nerve force.* It is surely more in accordance with reason to endeavour to explain the phenomena by the action of forces we know something about, than to attribute them to the influence of other forms or modes of force which are purely fanciful and fictitious. At any rate it will be time to call in the aid of such airy nothings when all attempts to explain the facts by known forces shall have failed. No one has yet succeeded in rendering it probable that the nerve current is *not* electricity while a great number

* Physicists and chemists see no difficulty whatever in assuming the existence of many modes of force of which they can form no conception, and think it very satisfactory to refer phenomena which they cannot understand to some at present undiscovered form or mode of ordinary motion; but if any one attributes these same phenomena to the influence of some equally undiscovered form of force having no connexion whatever with primary energy or motion, he is ridiculed, because, say the physicists and chemists, "there is but one force in kosmos!"

of well ascertained facts are strongly in favour of this inference.*

But if conclusive proof had been afforded that the nerve current was electricity, we should not even in that case have ascertained the whole truth, and, indeed, should have advanced but a little way towards a true explanation of nerve phenomena. For *action* and *work* are due not to force alone, but to the machinery by which the force is conditioned, and this is determined in nerve organs by the arrangement of the fibres and centres—in short, by the form or structure of the nerve apparatus. And this form and structure are the result of a long series of changes of the most complex character, which cannot be fully explained in the present state of our knowledge, but can be proved to be dependent upon the germinal matter; and since it has been shown that the nervous system at an early period consists entirely of germinal matter, and that in the fully developed state there is much germinal matter associated with every part of it that is active, especially all nerve centres and all peripheral organs, it is obvious that we cannot advance one step towards the explanation until we have determined the nature of the changes occurring in the germinal matter.

But unfortunately we are not yet acquainted with the exact *structure* even of the simplest nervous apparatus.

* It is a source of regret to me that my friend Dr. Child should have so mistaken my views upon this matter, as to tell his readers ("Essays on Physiological Subjects." Second edition, p. 277) that I look "upon nerve force as a form of vital force," which is a view contrary to that which I have taught for the last twenty years.

We do not know exactly what is essential for nervous action, and the study of the constitution of the ultimate active part of nerve tissues is a matter of the greatest difficulty. But how can we hope, without an accurate knowledge of the construction of the simplest type of nerve instrument, to learn much about the working of the most complex nervous apparatus? Is not the kind of work performed by an ordinary machine determined by its construction, and has not every bit of the work done a particular form or character stamped upon it which may be traced, as it were, through the machine to its designer? To say that the work done by any machine is the result of force, is, therefore, but a half truth,—nay, it is not truth at all, for force alone cannot do the work or produce the machine which performs the work. Both the work and the machine exhibit character or *form* which was not derived from force, but from mind, or whatever that may be called which governs, directs, designs. There is no mechanism, animate or inanimate, simple or complex, which has resulted only from the influence of ordinary force; and although it has been asserted over and over again that force *forms* and *builds* tissues, not the slightest evidence can be advanced in support of this arbitrary dogma. It would not be more absurd to assert that *motion* designs, originates, and creates, than it is to maintain that force *forms* and *builds*. Nor will all the energy, authority, and influence the physico-chemical school can bring to bear, succeed in forcing thoughtful and intelligent people to accept such assertions. What strikes one as most wonderful is that any one should try to make people believe that ordinary force can *form*, or has ever *formed*, any

mechanism or other thing in this world capable of working or acting.

Of Mental Nervous Action.*

After the admissions I have been obliged to make of the failure of attempts to demonstrate the mere structure of comparatively simple nerve organs, it may seem almost a waste of time to venture upon the consideration of the action of the highest and most complex of them all; but, in fact, opinions have been formed and conclusions have been arrived at upon the subject. There can be little impropriety, therefore, in enquiring what is the general conception of mental nerve action to be derived from contemplating the structure and arrangement of the tissues concerned, as far as these have yet been elucidated, in conjunction with a careful consideration of important general facts and principles discovered in studying other and less complex nerve phenomena.

There can be no doubt that the most important part of the mechanism engaged in mental action is situated in the grey matter of the cerebral convolutions; and the results of observations upon the structure, as well as experiments upon the action of other nerve organs, justify us in the conclusion that *nerve-cells* consisting of germinal matter and formed material, and *nerve fibres* composed of formed material only, are the active agents. These are so arranged

* It is hoped that the new facts and observations recorded in this section will, in some slight degree, atone for the occasional introduction of what will now be regarded by many modern authorities an obsolete metaphysic.

as to constitute a mechanism (if this term may be properly applied to it) of marvellous perfection and complexity. The fibres, many being of extreme tenuity, are seen to interlace with one another, and run in every conceivable direction, so that when the observer realizes the actual arrangement as it exists in a very small portion of grey matter, and this is the utmost he can hope to do, he marvels how it has been brought about. Though he is convinced that the whole has been, as it were, laid down according to a definite plan and has been designed to fulfil a special purpose, he is unable to picture to himself the gradual changes by which the result has been attained, and he cannot discover the laws which have governed them. There can, however, be no question that our knowledge upon these matters will increase as investigation advances, although it is not likely we shall ever be able to explain with exactness the nature of the power, force, or property which determines at the first the ultimate structure and exact arrangement the mechanism shall at length acquire. To state that this is due to crystallisation, or formifaction, or differentiation, and to offer any such vague assertion as an explanation of the facts observed, is not adding to our knowledge.

After having shown (p. 87) in what particulars the formation of the simplest structure differs from the process of crystallisation, it is unnecessary to discuss the question with reference to the highest and most complex tissue known. But even if we could explain the formation of the complex structure of the cerebral convolutions, we should have advanced but a little way towards a knowledge of mental action, for, as it were, behind all this structure,

operating now on one part of the mechanism, now on another, is the *mind*, the *will*, the *thinking power* itself. What is the nature of this, and how does it act upon the mechanism? If the conclusions to which I have been led with regard to the importance of germinal matter in all ordinary nervous acts be correct, it is almost certain that *mental nervous action is very intimately associated with changes occurring in a particular kind of living growing matter*. We find a large proportion of germinal matter present in the grey matter of every kind of brain, and at every period of life. Even in old age, when the proportion of germinal matter in the various tissues and organs of the body has become much reduced, a large amount is still found in the grey matter of the brain. Moreover, the mental excitement, wakefulness, and delirium, so remarkable in many cases of fever and inflammation of the membranes and superficial portion of the grey matter of the convolutions, are invariably associated with changes in the germinal matter. In such cases I find the masses of germinal matter are much larger than in the healthy tissue, and, in some instances they are twice as large. I have also seen the enlarged mass in the centre of the caudate nerve-cells dividing into several masses which resemble pus corpuscles, and have the same appearance as the pus corpuscles which are sometimes seen in epithelium (Pl. VIII., p. 34).

But if it be admitted that mental phenomena are entirely due to changes in the germinal matter of the cerebral convolutions, there will be much difference of opinion concerning the precise way in which this germinal matter

operates; and, in connexion with this question, it must be admitted there is much room for speculation. I shall venture to bring under notice the view which, in my opinion, appears, upon the whole, to be most in accordance with facts of observation and experiment. But, in the first place, I propose to refer very briefly to some of the opinions which have been entertained upon this matter, and to the general principles upon which these have been based.

Every one will admit that the nerve tissue of the brain is the instrument through which alone thought works and mind acts, and I think the facts I have advanced render it impossible for any one to deny that this instrument is formed by, or is the result of, changes taking place in germinal matter; but we are not now inquiring *how* the material channels which convey the mandates of the will *are formed*, but rather how these mandates originate, from what they emanate, and what is their nature.

Are Mental Nervous Actions of the Nature of Reflex Actions?—In all animals which possess nerve organs we find that an external impression is followed by a certain internal change, and we explain this by saying that the physical disturbance is conducted by the afferent nerves to the nerve centre, whence it is reflected by motor nerves distributed to the muscles, which are thus caused to contract, and in many cases the intensity of the contraction varies with the character of the external impression. Such are the so-called physical or reflex nervous actions. In mental nervous actions, however, the impression starts from within, not from without, and although certain of the lower mental operations may perhaps without impropriety be included

in the category of reflex actions, we are all conscious of others, and these the highest of all nervous phenomena and peculiar to man himself, which require no external stimulus for their excitation. These, on the contrary, attain their highest perfection when the mind is absorbed in contemplating its own peculiar states, and has succeeded, as it were, in withdrawing itself to the utmost possible extent from the influence of surrounding conditions which operate physically upon the peripheral portion only of a mechanism, the central portion of which is in some way under the immediate control of mind. To say, then, in answer to the question, "What happens in the brain when its possessor thinks?" that what he terms ideas and thoughts are excited by, and are the consequence of, changes occurring outside him,—the result of an external impulse,—and due to a sort of reflex action, appears to me a very unsatisfactory reply, not approaching an explanation. For, in the first place, if we admit that mental action results from external impressions, these must be stored up in some unknown manner, and lie dormant for a long period of time, while actions which are ordinarily termed reflex are characterized by immediately following the external impressions. Secondly, in mental nervous acts, no one has shown that the supposed mental reflex action bears any relation whatever to the external physical impulse supposed to excite it; or how is to be explained, upon the reflex hypothesis, the fact that a very slight external impression may excite excessive mental action, or *vice versâ*? Thirdly, when the mind is most active, ordinary reflex phenomena are often in complete abeyance. Fourthly, the organs concerned in ordinary

reflex actions are in an active state long before mental nervous organs are developed, and it is difficult to see why the mental apparatus should be so much slower in development than other reflex apparatus if it is of this nature. The reflex mechanism soon attains its highest state of perfection. The mental apparatus advances slowly in development, but continues to improve for years after it has been formed, and we can form no conception of the state of perfection it may possibly attain. The mental apparatus exhibits a *capacity* for altering its structure and of making itself more perfect. Fifthly, in man, mental actions continue to improve long after the organs concerned in reflex actions have begun to deteriorate. And, lastly, a capacity for mental action of the highest kind is not unfrequently associated with a nervous system below the average, as regards the performance of ordinary reflex acts. It is, therefore, doubtful if mental action is a kind of reflex nervous action.

Nor can it be maintained that mind is but a consequence of the action of the organs of the senses; for, although we are dependent upon these for obtaining the knowledge, with which the mind works, the mind itself can have nothing more to do with these or other organs, seeing that they may be entirely removed or destroyed, and the mind work as actively as ever. It cannot obtain new knowledge to work with; but the perfection of its working is one thing, the amount of knowledge acquired is another, and we know that these things are sometimes even in inverse ratio, one individual being remarkable for the excellence of his mental capacity, but having little knowledge, while another

has vast information of which he can make but little use for lack of intellect.

The Brain is not a Gland.—Some have looked upon brain as a sort of gland by which thoughts and ideas were formed or secreted, as if thought, which can neither be touched, weighed, measured, nor in any way physically estimated, was a thing allied to the bile, the saliva, or the gastric juice, which are material substances, and can be analyzed and otherwise experimentally studied. It would not be more unreasonable to maintain *design* or *will* to be a part of the material framework of the organism, than to assert that mind, like certain kinds of matter, is secreted. Thought is no more material than that peculiar capacity which makes living matter of a certain kind at length become oak, cabbage, dog, man, &c. Nay, it is further removed from the material, for while the property or power referred to influences the very particles of matter, and makes them take up certain fixed and definite positions, thought only produces a sort of evanescent vibration, which results in the expression of ideas which are themselves as immaterial as the thought itself.

Of Mind as a Function of the Brain.—Mental energy has been regarded as the *function* of the brain, but if it be so it is a *function* of a very different order from that discharged by other organs. *Function* implies an act in which will, purpose, design, are not concerned, and in which material changes can be proved to take place. The function of a gland is to produce a secretion. Certain conditions necessitate the production of this or that particular secretion, which may vary to some extent, according as the conditions

are changed. The function of a muscle is to contract and become relaxed, but the material change only occurs in definite directions, necessitated by the structure of the instrument and the force which acts upon it. The exercise of choice is neither possible nor conceivable. So, too, with reference to the function of nerves. These transmit currents. The paths which the currents are to traverse having been determined and formed, the currents are developed and transmitted along the nerves.

But the discharge of *function* on the part of the organ of the mind is an operation very different from any of these. The great characteristic in this case is choice—selective capacity. If the cells of the liver chose for themselves whether they would secrete bile or not, or determined the kind of bile to be secreted, or the bile chose for itself by which ducts it should pass, whether it would flow quickly, slowly, or not at all; if the muscle contracted now in one part and now in another, according as it willed—if it elected to contract in one direction, and then in a different one; if the nerve cells decided among themselves which should produce current and which not: if the current chose to run along one fibre at one time and then along another, according to the object it had in view—then, but only then, as it seems to me, could mental activity be regarded as in any way analogous to the function of an organ or of a tissue. To look upon mental action as a mere function of the brain seems to be a fundamental error, and one which those who have really studied the structure and action of secreting organs and nerve organs could not make.

Mental activity may rather be compared with that mar-

vellous power, property, or capacity, which enables the liver cell to *form* what we call bile, which renders possible that change in shape of the ultimate particles of muscle which gives rise to contraction, and determines the change in the ultimate molecules of nerve matter upon which the current depends; but this power is not the function; it is that which alone renders function possible. But even this comparison is not a true one, for the power above referred to acts as if it were of some necessity, while the remarkable characteristic of mental action is freedom of choice. Certain conditions being present, the liver cell *must* form bile, the muscle *must* contract, the nerve cell *must* give rise to, and the nerve fibre *must* transmit, the current; but is it conceivable that under certain conditions, actual or supposed, the brain *must* think? Is what I am now writing but the result of the distribution of a little extra proportion of certain nutrient constituents and oxygen to my nerve cells which thereby compels me to say all these things? Have I no choice?—*must* I say all this, and in the precise way in which it is here said? All these things would surely have been said in a far better and more perfect manner if the ideas had been formed like a secretion by a healthy gland, independently of experience and without any efforts of my own. All our glands perform their work perfectly when their formation is complete. They require no teaching, and they work without effort, and for the most part without our knowledge. Again, there is nothing in the action of a gland which at all corresponds to the improvement in capacity which results from exercise, so remarkable in the case of cerebral nervous action. The general tissues and

organs, at least of those persons who have reached or passed middle age, performed their functions some years ago as well as, and I fear in some respects even better than they do now. *Will* has exerted, and can exert upon them, no direct influence. But it is very different with regard to the organ of the mind and the tissues concerned in intellectual action. Every one knows that the degree of perfection which these have attained or will attain is determined in great measure by his own efforts—by his own will. The thinking instrument of one individual is not capable of being perfected in the same degree as that of another, but is is quite certain that each may be improved and made to work more perfectly, if its possessor determines that this shall be; nay, I think I may say, if he will not interfere actively to prevent its improvement, for the natural tendency of the mind is to exercise itself, and, in doing so, the instrument which it directs necessarily improves. As the mechanism becomes more perfect, the pleasure afforded by its working becomes greater, and to real desire and sustained effort on the part of the mind soon succeeds improvement in the structure of the healthy instrument, by which the attainment of the end desired is rendered possible.

But no doubt the degree of perfection to which an individual can attain in giving expression to his thoughts is limited by the excellence of structure reached by the mechanism upon which thought operates, and this will of course depend very much upon original developmental capacity, but yet in no small degree to the training to which it may have been subjected from early youth when it was in an eminently plastic state, and capable of being so dis-

posed as to attain ultimately a very high state of efficiency. In order to produce the greatest possible results, the thinking power, the selective capacity, must have at its disposal a mechanism of eminent perfection capable of being impressed by and of giving exact expression to the slightest undulations of the matter upon which the mind immediately acts.

Of Mental as compared with Mechanical Action.—If a machine could be made which would change from time to time, of its own accord, the kind of work it performed without any alteration being made in its mechanical arrangements, a rough comparison might be drawn between such a machine and the brain, but a machine of the kind supposed exists not, and is not conceivable.

Let us consider if the actions of the mental apparatus exhibit any analogy with those performed by a vast number of highly complex machines so arranged as to be under the influence of one person, this or that being made to work according as he willed? In order to make the case as strong as possible, we may further suppose every machine to be constantly wound up ready to be brought into operation on the instant, and capable of being stopped with facility. Or can we imagine an immense telegraph system which, besides communicating information, shall be capable of effecting mechanical work? The supposed machines have no breaks or any of those arrangements to prevent injury or over-action, as in the various kinds of apparatus made by us. And further, our imaginary machine ought to be made of soft material, like brain-matter, and every portion of it should be capable of gradual renovation. Such conditions,

we know, cannot possiby be fulfilled, and therefore no true analogy can exist between any machines made by us and the nervous mechanism concerned in mental action. But admitting that they might be, and without laying stress upon the fact that the nervous apparatus, unlike the machine, keeps itself in order and in working condition if only the rest needful for its repair and renovation be granted, we have yet to find the power, the hand that guides the mental engine, its superintendent, who bids the wheels revolve or stops them, who allows the work to proceed or checks it, as he wills. What sort of guide can we find in the case of the mental machine, where is he seated, and how does he influence the complex apparatus under his immediate individual care and sole control? In what spot in the brain are we to search for him? But do we not know that the structure of the grey matter is such as to preclude the possibility of the existence of anything exhibiting any approach towards any mechanical arrangements known? We understand its construction sufficiently to justify us in concluding that the nervous matter operates in a manner different in principle from the action of any known mechanism.

It has been said that in the brain we have "molecular machinery" *built* by the sun, but no one has shown what this supposed molecular machinery is like, what is its structure, how it acts, or how it is formed. Molecular machinery is a term which conveys no idea whatever to the mind. No one could draw or make a model of the supposed molecular machinery. We may have molecular matter, and we may have machinery, but there are no machines the

molecules of which are active, and there are no molecules which act like machines—in fact, there is no molecular machinery, and, it is scarcely necessary to say, nothing whatever has been built by the sun. The expression is altogether incorrect, is calculated to mislead, and, there is reason to think, has led many to accept conclusions utterly at variance with established truths. The phrase "properties of the molecules" is made to do duty in the same way, and we are told that the properties of a living being existed potentially in the molecules of cosmic vapour of which his body is made; but can we hope to learn much by discussing the possible properties of the hypothetical molecules of hypothetical primitive nebulosity? The brain we do know something about, and we can learn much more concerning it, but of the primitive nebulosity of ourselves, or of the world we inhabit, we can know nothing and can learn nothing.

Of Thought as a Result of Chemical Action.—Some have expressed the opinion that thought was to be explained by the oxidation of chemical compounds in the brain. Judging from some of the remarks which have been made concerning the supposed chemical changes in nerve matter, one would infer that the brain, instead of consisting of millions of separate anatomical units exhibiting an elaborate structure and arranged in beautiful order, was but a mass of fatty albuminous pulpy material, rich in phosphorus, the action of which was determined by the oxidation of certain of its component elements, particularly the last, the oxygen being carried to the nerve pulp, and the products of chemical change being removed from it by the blood circulating in the vessels freely ramifying in the substance of the pulpy

mass. But although there is no doubt that in the *expression of thought* chemical changes takes place in the nerve matter, it has by no means been proved, nay, I cannot admit that the arguments advanced render it even probable, that thought itself results from chemical change. It would be more in accordance with what we know to conclude that thought preceded and determined the chemical change occurring in particular particles of the brain matter, than that it was a consequence of it. Chemical change will not alone account for any vital acts whatever. If the movements of part of a mass of living matter in advance of other parts were due to chemical action, such movements would soon be produced in the laboratory, but chemistry has not yet advanced one step in this direction. The special action of any particular apparatus is not usually explained by asserting that it is due to the disintegration and oxidation of its constituent parts—of wheels and cranks, for example—but yet some will have it that the action of the cerebral apparatus is to be satisfactorily accounted for by the disintegration and oxidation of the matter of which it is composed.

Is the Brain to be looked upon as a Voltaic Battery?—"Another hypothesis, to the legitimacy of which no objection can lie, and one which is well calculated to light the path of scientific inquiry, is that suggested by several recent writers, that the brain is a voltaic pile, and that each of its pulsations is a discharge of electricity through the system. It has been remarked that the sensation felt by the hand from the beating of a brain bears a strong resemblance to a voltaic shock, and the hypothesis, if followed to its consequences, might afford a plausible explanation of

many physiological facts, while there is nothing to discourage the hope that we may in time sufficiently understand the conditions of voltaic phenomena to render the truth of the hypothesis amenable to observation and experiment."* By adducing in its favour such a statement as that about the resemblance of the beating of a brain to a voltaic shock, Mr. Mill upsets his favourite hypothesis, for it is certain that if there be any resemblance between a brain and a voltaic pile it is not of the kind implied.

But it may be that each little brain cell with its connected fibres in some way resembles a minute voltaic battery with its wires; the matter of which the cell is composed undergoing chemical change, in the course of which slight electrical currents are developed. These being transmitted by the fibres ramifying to different parts exert an influence upon distant tissues and organs among which they ramify. In this case some further arrangement is required by which the action of particular cells and fibres is determined or prevented. Perhaps the closest analogy we can draw between cerebral action and that of an electrical battery is the following:—We may suppose in the brain multitudes of minute active galvanic batteries with their delicate conducting wires or threads ramifying over extensive tracts of tissue, the action of which is determined by the currents traversing the wires. Situated among these wires or threads, we may suppose little bodies intimately connected with one another which are capable of undergoing alterations in form like the amœba, white blood-corpuscle, and other forms of living germinal matter. Not the slightest movement, though

* Mill's "Logic," p. 18.

it only amount to gentle quivering, can occur in any part of these bodies without an effect being produced upon the currents which traverse the delicate wires impinging upon different parts of their surfaces. Points in a vast number of circuits differing widely in their ultimate distribution are thus brought, as it were, within the influence of it may be each of these little masses of living matter, and the rate of transmission of the current through many different wires having different destinations and acting upon diverse machinery may thus be affected at the same moment, determining a variety of actions. But if it be admitted that the brain in structure and action resembles such an arrangement of minute voltaic batteries and conducting wires, we have to explain how all these were formed and made to take up the positions they occupy in relation to one another and to other organs before we can give any satisfactory and complete explanation of its action. For the kind of work performed by a machine is due to its structure as well as to the forces by which the machine is set in motion. And further, the movements occurring in the little bodies supposed to act upon the currents transmitted by the threads must take place spontaneously. It need scarcely be remarked that any such action in a machine or any mechanical or chemico-mechanical contrivance whatever, is impossible.

On expressing Thoughts.—But in considering the nature of mental nervous action, it is necessary in the first instance to distinguish clearly between the mental action—the actual thought; and its expression. The conversion of thoughts into symbols which others can appreciate is due to a highly elaborate mechanism working in the most perfect manner,

but it by no means follows that if we understood exactly the manner in which this mechanism worked, we should therefore be able to form an accurate conception of the nature of thought itself. Thoughts and ideas may, and in some cases do, undoubtedly exist, although they cannot be expressed in any way in consequence of the derangement or destruction of the mechanism concerned in *expression.* And in certain forms of cerebral disease intellectual action is performed, although the mechanism concerned in expression is completely deranged. Ideas are formed by the mind, and although the person can indicate this and convince us by his gestures that the idea is in his mind, he is quite unable to express it and make it intelligible to others. The mechanism concerned in expressing thoughts consists of a nervo-muscular apparatus arranged with such consummate skill, and occupying so small a space, that it is possible for the mind to form but a most imperfect conception of the arrangement of even a very small part of it.

It is difficult in many cases to decide to what extent the apparatus concerned in expressing ideas is engaged in silent reasoning and cogitation. When we think over complex matters, and reason upon them, we work with certain mental images or symbols of the things, but certainly not with the verbal expressions of them, nor even with their representatives, but with something far short of either, though sufficiently distinct and exact nevertheless. A great number of these images may be marshalled, as it were, before the mind almost in a moment, and conclusions arrived at which would require the greatest cleverness and a long time accurately to express. And in but too many

instances, after making the greatest efforts, we only succeed in conveying to the minds of others the roughest, coarsest representation of a mental image which to us is distinct, clear, and perfect in all its details. And it is well known how much more fatiguing is the operation of expressing than that of thinking and drawing conclusions mentally. The results of a few hours' thinking, obtained without any perceptible exhaustion and without any conscious effort, may require many days' hard labour to reduce to a form intelligible to other minds, and in this operation the bodily health may suffer, as well as the mental vigour be impaired. It would therefore seem as if thinking and cogitation belonged to the class of actions which I have distinguished as *vital*, and which are performed without waste or change in constitution of material substance, while the *expression of thoughts* undoubtedly involves material changes of the most active kind. We may roughly compare the first to the acts of an engineer who directs and controls a machine, and the last to the work performed by the machine itself. The engineer or superintendent, it may be said, merely exerts a directing and controlling influence which has nothing whatever to do with the combustion of coals or the falling of the weights, uncoiling of the spring, &c. He contributes nothing that can be weighed or measured towards the work performed by the machine. He can exist without the machine, and the latter may act without him, yet we all know how very much the result produced, as regards both the quantity and the quality of work performed, is due to his interference.

Of the Living Matter concerned in Mental Action.

I will now refer further to the results of anatomical investigation. Near the surface of the grey matter in that extensive layer above the planes in which the caudate nerve-cells are situated, which is generally said to be composed of delicate nerve-fibres and "granular matter," I have succeeded in demonstrating multitudes of very small masses of germinal matter lying amongst the finest branches of the nerve fibres. In some places there are aggregations or collections of these bodies, which are extremely delicate, and become disintegrated very soon after death. Some sections appear to consist almost entirely of these bodies, so great is their number. They seem to be connected together by very delicate processes of the same transparent material. Masses of germinal matter thus situated are arranged very favourably for influencing the fine nerve-fibres which ramify amongst them. The slightest change in their form could not fail to affect nerve currents traversing these fibres, and as we are now well acquainted with the active movements of germinal matter, it is impossible to help suggesting that the movements occurring in these masses of germinal matter produce a direct effect upon the adjacent fibres, and that these *vital* movements or vibrations occurring in matter of excessive tenuity constitute or are rather the immediate consequences of mental vital action. The directions in which the living matter is made to move by the conscious life-power which directs it, will determine the

particular cords of the nerve mechanism to be struck; special movements expressing the inward ideas then follow. If this be so, mind is the vital power which is associated with this the most exalted form of living or germinal matter, so arranged that the slightest change occurring in it may produce indirectly an effect through the influence of a most elaborate mechanism, brought into very intimate relation with it. Although I am not prepared to deny that the germinal matter of the caudate nerve-cells of the grey matter of the cerebral convolutions is concerned in mental nervous actions, there are many arguments which lead me to think that this is not the material substance which is immediately influenced by the mind, but belongs rather to that wonderful mechanism which is concerned in the expression of thought, and in the conversion of ideas into symbols.

Of the Character of the Germinal Matter taking part in Mental Operations.—Some might anticipate that the matter immediately influenced by mind would exhibit some remarkable structure and arrangement, but those who have studied the characters of living matter in the lowest and highest organisms will not expect to find this, the highest form, exhibiting any structure whatever or possessing any peculiar chemical composition. They will be prepared to find the highest forms composed of the same colourless, structureless, moving substance which constitutes the living matter of the lowest organisms, and they will look for a difference in power—in endowment, not for any material difference. The germinal matter of the embryo of the highest and most complex being in nature cannot be distinguished from that

constituting the germ of a very simple creature, nor does the germinal matter of the nerve-cells of the human embryo exhibit any special characters. We should therefore anticipate that the highest form of germinal matter known, that which takes part in mental action, would agree in its characters so far as we are able to determine them, with other forms. The difference, vast as it is, is a difference in power, which, however, we can only estimate by the results of its action—by the effects produced by it. In the living state this form of living matter is no doubt perfectly transparent, of excessive tenuity, and exhibits no characters which would enable us to form any notion of its exalted powers. These powers, properties, or endowments are unquestionably due, not to its chemical composition or to the peculiar arrangement of its particles as compared with other forms of germinal matter, but solely to that wonderful force, property, or power, which I would place under the head of *vital power*.

We should anticipate that of all kinds of germinal matter known, that concerned in mental nervous action would be most evanescent and prone to rapid decay and disintegration after death. It is therefore not surprising that in many cases no trace of the delicate masses of germinal matter I have described should be discovered. And I feel sure that what I have been able to demonstrate affords but a very imperfect idea of the real number and arrangement of the masses of germinal matter which exist in the living state. We should expect that change would almost immediately follow the death of the individual, and that this form of germinal matter would be completely broken down long

before other kinds existing in the same organism had ceased to manifest vital phenomena. And I may remark that the length of time during which different forms of germinal matter survive the general death of the organism varies greatly—some dying very soon, while others live even for days. The capacity for living under altered conditions becomes greater as we descend from the highest towards the lowest kinds of germinal matter, the highest being killed by slight alteration in the surrounding circumstances, while the lowest resist very considerable changes, and for long periods of time. The pus corpuscle and the particle of *contagium*, both which are descendants of the germinal matter of the organism, retain their vitality under conditions which certainly would have been fatal to the germinal matter from which they sprang.* The power of resisting the destroying influence of varying external conditions seems to increase as germinal matter becomes more and more debased.

And it is interesting to note here, that this, the highest form of germinal matter, when exposed to altered conditions, dies, instead of, like many lower forms of germinal matter, growing, and mulitiplying, and giving origin to masses of germinal matter possessing different properties. In inflammation this is, so to say, protected by the lower forms of germinal matter in the immediate neighbourhood, taking upon themselves increased growth and multiplication, and absorbing the excess of nutrient matter present. The germinal matter of the connective tissue of the pia mater

* See my Report on the Cattle Plague, 1865.

and adjacent cerebral tissue, that of the vessels and probably also that of the large caudate nerve vesicles of the grey matter, may all be involved by inflammatory change, and the germinal matter taking part in mental nervous action escape. I think that the mechanism concerned in expression may undergo the most serious changes while the highest form of germinal matter may escape, and even retain its integrity; although there is no longer any possibility of proving that this is so, if the nerve apparatus concerned in expression is deranged or destroyed.

And I may further remark that different forms of germinal matter in all parts of the organism suffer in inflammation in different degrees and in different order. Generally those which are of least importance, and which, as regards their formative capacity, are lowest in the scale, are the first to suffer. The germinal matter of epithelium and connective tissue are soon affected; that of the capillaries, including the white blood-corpuscles, follows next in order; then that of fibrous tissue, cartilage, and bone, the germinal matter of the muscular fibre-cells of the small arteries and veins; while that belonging to the voluntary muscles, that of the peripheral nerve organs and the peripheral ramification of the nerves is the last to be involved. In like manner the germinal matter of the several tissues entering into the formation of the great central nerve organs, is affected in different order. The connective tissues, fibrous tissues, capillaries, arteries, and veins being involved before the nerve elements themselves are attacked, and of these the lowest as regards function suffer before those which are concerned in the most exalted nerve actions. These last seem to be pre-

served from damage for a long while, but when at last they become involved, death succeeds, before time has elapsed for any great degree of morbid change to have taken place; while in other cases the germinal matter with the tissue may have completely degenerated without the death of the individual having been occasioned.

The living matter concerned in mental operations is that which is last formed, and is probably the highest condition which living matter has yet assumed. Like other forms taking part in the formation of the various tissues and organs belonging to the organism, it has been derived by direct descent from the original germinal matter of the embryo. From the growth and subdivision of that primitive mass have resulted, and in definite and prearranged order, numerous forms endowed with marvellously different powers. But the germinal matter which forms cuticle, that which produces fibrous tissue, muscle, nerve or bone, the germinal matter which gives rise to biliary secretion, to the saliva, and to the gastric juice, as well as that which takes part in mental nervous action have, so to say, one common parentage ; and if, as these several forms are evolving themselves, or are being evolved, the conditions which alone render possible progress towards their highest state becomes modified, the attainment of perfection is prevented. Such cases are familiar to us under the term *arrested development*, in which, up to a certain period of life, everything seems to have proceeded correctly, but then in consequence of some disturbing action modifying the process of nutrition and affecting the division and subdivision of the germinal matter, the structures which would at length have resulted in due

course can *never* be formed. Of all the changes originating in this way, those affecting the germinal matter taking part in the development of the higher parts of the nervous system of man lead to the most disastrous results. That gradual development of the mental powers *after* the individual has ceased to grow, which is one of the most remarkable of the characters by which man is marked off from the lower animals, is rendered impossible, and the mental powers of the child or of the infant remain associated with the organism of the adult.

The new powers which germinal matter acquires as development advances arise in some way as the new centres (nuclei, nucleoli) originate in pre-existing centres,—when, it may be said, matter comes under the influence of the vital immaterial agency, and sets out upon a new course which has been appointed. How the new powers which it has acquired are communicated to it, it is as impossible to suggest as it is to explain how these new centres originate. And it may be asked what is to be understood by "centre," for it is obvious that the centre demonstrated by low powers has within it numerous centres, as may be proved by examination under glasses magnifying very highly, and there is reason to believe that if our powers were increased ten, twenty, or a hundred-fold, we should approach but a little nearer to the unrealisable actual centre; and I can conceive that in the highest forms of germinal matter new centres of living matter are constantly welling up, as it were, in already existing centres, having within themselves infinite and inexhaustible power for the endowment of new centres.

The germinal matter taking part in mental action, like other forms, is no doubt liable to defective as well as irregular and monstrous growth, even during and after the adult period of life. These changes, which may be temporary or permanent, are probably more under the immediate influence of the will than is the case as regards changes in other forms of germinal matter. But there can, I imagine be little doubt that, just as by exercise up to, and in many cases even after, the middle period of life, we are enabled to increase the power of certain muscles and the perfection of certain movements which are associated with increased formation of nerves and nerve-cells in the nerve centre governing them: so, by habitually indulging in certain trains of thought, we may perhaps effect the increase of the germinal matter concerned, until at last this preponderates so much over other portions taking part in other kinds of mental action that it alone is exercised, while the rest remains hardly active at all or quite dormant. Every lunatic asylum affords what I conceive to be examples of this, and it is not impossible in certain instances to distinguish the cases in which the mental living matter itself is deranged from those in which the mechanism concerned in the expression of ideas is the seat of disease. On the other hand, what remarkable instances do we meet with of the gradual but continuous improvement of the mental powers even in advanced life, where they have been subjected to unremitting but judicious exercise from early youth onwards!

The mental excitement and incoherence, followed by complete suspension of mental powers, which occur in inflammation and other conditions where the germinal

matter takes up an abnormal proportion of nutrient material, are readily explained, as are also those cases in which impaired intellectual action follows as a consequence of the disease. Where the morbid change has proceeded to a considerable extent, there may be permanent impairment, while in cases where only slight change has occurred, only temporary derangement may result.

Of the Nature of Will, and of the Life of Germinal Matter taking part in Mental Operations.—Many considerations lead me to conclude that *will*, so far from being a result of certain chemical changes induced in matter, should rather be regarded as the *power which influences the material particles and causes them to move and take up new positions.* It seems to me that this power is of the same order as that which induces the movements in germinal matter, and which I have ventured to call *vital power*. I conceive that the change in form of the germinal matter is a consequence of some influence exerted upon the particles immediately preceding their movement. This active cause, the nature of which we know nothing, and which gives rise, we know not how, to material changes which, in the case of some of the lower forms of living matter, can be seen distinctly, constitutes the *vital power* of the *germinal matter*. This is, as it were, the starting point of all those complex phenomena which occur whenever a voluntary act is performed, and, as regards the material changes in the germinal matter concerned in mental operations, is *the mind*. The germinal or living matter may be said to be the domicile of the *ego;* but so rough are our methods of investigation that when we commence to search for the *ego* we destroy its habitation, and the *ego* escapes whither we cannot follow it. The par-

ticles of the matter which were directed and changed by it may be directed and changed in new ways; but it is absurd to think we can discover the directing, changing *ego* in the dead and disintegrated matter which remains after it has gone, and equally absurd to deny its existence because we cannot find it, or to affirm that it is mere force which has changed its mode or form. Certainly the dead matter we see and touch may in some sense be regarded as having once formed a part of the material framework of the living being, but it was then in a very different state, for that which gave it body and made it what it was has since gone. To assert that the material elements of the grey matter of the brain of a dead man are all that constituted the active living organ of the mind, would, indeed be strange. It is that which has escaped that alone acted through the living matter upon the mechanism which is subordinated to it. But the mechanism may work although in a different way if affected by other influences. A chance breath of air may throw the strings of the lyre into vibration and longing listeners may even think they hear the measured strains they know so well, but it is soon discovered how different are the accidental unmeaning notes from the harmonious cadences in which the successive undulations of the mind were wont to be expressed. Again, the instrument may be deranged, in which case not a conception of the most vivid imagination can make itself known. The learned declare that an instrument is hopelessly out of order, and consider that that is all that need be thought or said about the matter.

If my conclusions tend towards the truth, it almost follows that before we can be in a position to form an

opinion upon the nature of a mental process we must at least be able to form a conception of the actions which immediately precede the observed *changes of form in a mass of very simple living matter that can be easily subjected to investigation, and of the antecedent change which determines these actions.* But unfortunately at present we have no means of investigating this most important question. We cannot explain why one part of a living mass should move in advance of another. To say the movement must be the consequence of *some antecedent phenomenon* will only satisfy those who are content to receive arbitrary assertions in place of explanations. The supposed antecedent phenomenon is unknown, and is, perhaps, in the present state of things, unknowable. It is probably altogether wrong to use the word *phenomenon* here at all, the antecedent in this case not being a phenomenon. Until the movements of the living matter of an amœba or a white blood-corpuscle have been satisfactorily accounted for, it is not likely we shall be able to arrive at any positive conclusions concerning the nature of the actual changes in the living matter which determine mental nervous actions, but it is surely a step in advance if it is rendered probable that these are intimately related to the vital changes in germinal or living matter. The arguments I have advanced in favour of the view that the highest mental actions are associated with vital movements, and are, in fact, vital actions occurring in living matter, appear to me to be justified by the facts I have adduced; and although there seems to be at present no possibility of actual proof, I venture to think that the evidence upon which my view rests, indirect though it be, will not be regarded as inconclusive.

NOTE.

*** Since the first edition of this work was published, Mr. Huxley's essay on the "Physical Basis of Life," has been submitted to a very just but clear and searching philosophical criticism by Mr. James Hutchison Stirling, of Edinburgh, whose excellent treatise I very strongly recommend my readers carefully to study. I should have taken from it many extracts, but the work is easily obtained, and readers should see it in a complete form. Mr. Stirling concludes in the following words, "In short the whole position of Mr. Huxley, that all organisms consist alike of the same life matter, which life matter is, for its part, due to chemistry, must be pronounced untenable—nor less untenable the materialism he would found on it."

"As regards Protoplasm in relation to Professor Huxley's essay on the Physical Basis of Life," by James Hutchison Stirling, F.R.C.S., LL.D. Edinburgh: William Blackwood and Sons. 1*s.*

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